June 1919. BOTANICAL SERIES. VOL. X, No. 2.

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

STUDIES IN INDIAN SUGARCANES, No. 4

TILLERING OR UNDERGROUND BRANCHING

BY

C. A. BARBER, C.I.E., Sc.D. (Cantab.), F.L.S

Government Sugarcane Expert, Madras

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PRINTED AND PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA

W. THACKER & CO., 2, CREED LANE, LONDON

Agents for the Sale of Government Publications.

IN THE UNITED KINGDOM.

Constable & Co., 10, Orange Street, Leicester Square, London, W.C.

Kegan Paul, Trench Trübner & Co., 68-74, Carter Lane, E.C., and 25, Museum Street, London, W.C.

Bernard Quaritch, 11, Grafton Street, New Bond Street, London, W.

P. S. King & Sons, 2 and 4, Great Smith Street, Westminster, London, S.W.

H. S. King & Co., 65, Cornhill, E.C., and 9, Pall Mall, London, W.

Grindlay & Co., 54, Parliament Street, London, S.W.

T. Fisher Unwin, Ld., 1, Adelphi Terrace, London, W.C.

W. Thacker & Co., 2, Creed Lane, London, E.C.

Luzac & Co., 46, Great Russell Street, London, W.C.

B. H. Blackwell, 50 and 51, Broad Street, Oxford.

Deighton, Bell & Co., Ld., Cambridge.

Oliver & Boyd, Tweeddale Court, Edinburgh.

E. Ponsonby, Ld., 116, Grafton Street, Dublin.

ON THE CONTINENT.

Ernest Leroux, 28, Rue Bonaparte, Paris.

Martinus Nijhoff, The Hague, Holland.

IN INDIA AND CEYLON.

Thacker, Spink & Co., Calcutta and Simla.

W. Newman & Co., Calcutta.

R. Cambray & Co., Calcutta.

S. K. Lahiri & Co., Calcutta.

B. Banerjee & Co., Calcutta.

The Indian School Supply Depôt, 309, Bow Bazar Street, Calcutta, and 226, Nawabpur, Dacca.

Butterworth & Co. (India), Limited, Calcutta.

The Weldon Library, 18-5, Chowringhee Road, Calcutta.

Rai M. C. Sircar Bahadur and Sons, 75-1-1, Harrison Road, Calcutta.

Higginbothams, Ld., Madras.

V. Kalyanarama Iyer & Co., Madras.

G. A. Natesan & Co., Madras.

S. Murthy & Co., Madras.

Thompson & Co., Madras.

Temple & Co., Madras.

P. R. Rama Iyer & Co., Madras.

Thacker & Co., Ld., Bombay.

A. J. Combridge & Co., Bombay.

D. B. Taraporevala, Sons & Co., Bombay.

Radhabai Atmaram Sagoon, Bombay.

Sunder Pandurang, Bombay.

Gopal Narayan & Co., Bombay.

Ramchandra Govind & Son, Kalbadevi, Bombay.

N. B. Mathur, Superintendent, Nazir Kanun-i-Hind Press, Allahabad.

A. Chand & Co., Lahore, Punjab.

Rai Sahib M. Gulab Singh & Sons, Mufid-i-Am Press, Lahore.

Superintendent, American Baptist Mission Press, Rangoon.

S. C. Talukdar, Proprietor, Students and Company, Cooch Behar.

A. M. & J. Ferguson, Colombo, Ceylon.

TABLE OF CONTENTS.

LIST OF PLATES.

STUDIES IN INDIAN SUGARCANES, NO. 4.

TILLERING OR UNDERGROUND BRANCHING.

BY

C. A. BARBER, C.I.E., Sc.D. (Cantab.), F.L.S.,

Government Sugarcane Expert, Madras.

[Received for publication on 18th August, 1918.]

INTRODUCTION.

THE present research dates back to observations made in 1913, which showed that, in certain Punjab sugarcane varieties, there were differences in the canes growing in the same clump.[1] These were found to be early and late in origin, the former being thin and long, with short joints at the base, and the latter thicker and shorter and commencing with much longer joints. A certain number of dissections had been made of the underground, branching portion of cane seedlings and wild Saccharums, and it was decided to commence a systematic study of this part of the cane plant in the field, in order clearly to demonstrate the true relations of the differing canes in each clump. As additional points of interest, referred to below, presented themselves, the series was greatly extended, and during the past two years a very large number of cane stools have been carefully studied (*cf.* list on pp. 99 and 100).

For a proper understanding of the branching system of any plant, it is necessary to follow it from its earliest stages, and a study has accordingly

[1] Barber, C. A. Studies in Indian Sugarcanes, No. 1: Punjab canes, *Mem. Dep. Agri., Ind., Bot. Ser.*, Vol. VII, No. 1, May, 1915. This Memoir will in future be referred to as Mem. I. A second paper by the same author, Studies in Indian Sugarcanes, No. 2: Sugarcane seedlings, etc., Vol. VIII, No. 3, in the same series, will be referred to as Mem. II, while a third, Studies in Indian Sugarcanes, No. 3: Classification of Indian canes with special reference to Saretha and Sunnabile classes, will be referred to as Mem. III.

been made of the germination of the sugarcane seed and the sprouting of planted sets.

The important question of tillering soon connected itself with the dissection work, it being well known that, not only do the thick canes differ considerably in this respect among themselves, but, as a whole, they tiller much less freely than the indigenous Indian canes. Unfortunately there appear to be few accurate observations published on the tillering of Indian canes, and our own notes are far from complete. It is, however, hoped that the facts here presented will give a stimulus to this important side of crop investigation. Even in the tropical sugarcane countries, although a vast number of observations have from time to time been made, there are few papers dealing with the subject from a scientific point of view, and the great bulk of the notes made are not available for our purpose. Spacing, which has given rise to so many experiments in such crops as wheat and paddy, appears to have been occasionally tried in sugarcane; but the results are not easily obtainable, and no help can be got from those crops which are grown for the production of grain. A summary has been prepared of the literature of this part of the subject.

Attention was soon arrested by the fact, stated by various observers, that, during the lifetime of a cane plantation, a great many deaths occur, so that the number of shoots in early stages greatly exceeds that found at crop time. These observations have been made entirely with thick canes, and doubts arose in our mind as to whether they were equally applicable to Indian canes, as the deaths were by no means obvious in the plots. A series of shoot countings once a month was accordingly instituted to throw light on the question, but the results of these are not yet available for publication.

Incidentally, in the course of dissection, it was observed that different cane varieties showed considerable differences in their mode and degree of branching; and not only was this the case with individual varieties, but whole groups could without difficulty be distinguished from one another in this respect. The degree of branching in the Indian canes was seen, as a whole, to differ very considerably from that in thick canes, and this led to a study of that of wild Saccharums, when it was found, as expected, that the Indian canes stood half way between the wild species and the thick canes of the tropics. A further stimulus was thus added to the work, and it was attempted to discover, in the branching of the cane varieties, a means of tracing the origin of the cultivated canes from their wild ancestors, and, among the Indian canes, to select such as might be considered the more primitive,

and thus establish a connected series from the wild grasses to the thick canes of the tropics.

Lastly, differences were observed in the richness of the juice in the early and late canes of a plant, and these did not altogether tally with the views held regarding the richness of the thick and thin canes in tropical cane fields. The literature of the subject is punctuated by references to the relative richness in the juice of the "mother" cane and its branches, but, as no dissections seem to have been made, it is difficult to understand how the various observers distinguished these two classes of canes. There is obviously great confusion on the subject, for one observer, after stating his opinion, admitted that the mother shoot need not of necessity be the original main shoot of the clump but was the "thickest and best grown"! As will be seen, the result of our study is exactly the reverse, in that the main shoot is thinner and less well grown than its branches. This is indeed perfectly natural, when we consider the available equipment of leaves and roots in the young cane, as compared with that at the disposal of branches formed when the plant has grown up.

The dissection of the cane stool is a rather intricate and laborious piece of work. Upon taking it out of the ground, each clump is seen to be covered by a dense mass of tough roots, among which the soft buds are hidden, and these roots have all to be carefully cut away before the nature of the branching can be seen. The planting material with us consists of sets or pieces of cane on which there are at least three healthy buds, and these buds, usually all of them, develop into larger or smaller plants, which, however, are quite separate and only influence one another as regards the space available for their independent growth. It is usually impossible to make the dissection unless these plants are cut out and dealt with separately. In the list of dissections given on pages 99 and 100, the number of clumps and plants are therefore enumerated for each variety.

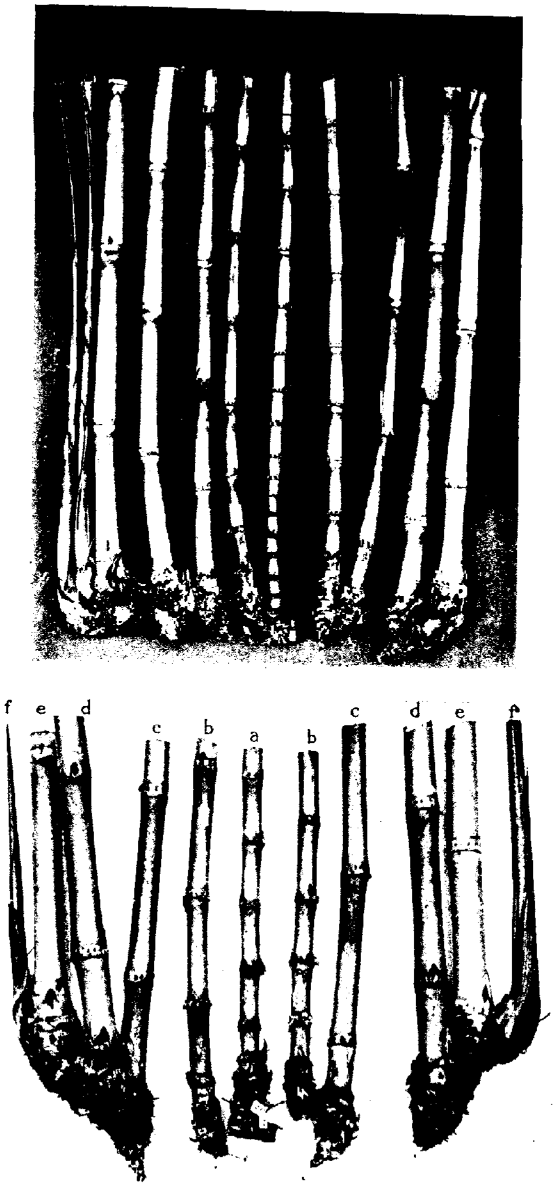
The main dissecting work was done in the 1916-17 and 1917-18 seasons, and in each year clumps were examined at two stages of growth for entirely different reasons. The first was at about four months, for the determination of the rate of cane formation; and the second at about eight months, for the study of the canes formed at crop time. It was soon found that, after this latter date, no new canes could be started in time to mature. In 1916-17, the dissections were largely concentrated on the Saretha and Sunnabile groups, which at that time had recently been separated and were being described. Six varieties of each of these groups were examined, and to them were added a few

from other groups and some thick canes and wild Saccharums. Altogether 51 clumps containing 133 plants were dissected during this season. The results of this work, briefly alluded to in Memoir III (pp. 156–160), were so suggestive and interesting that a fuller series was projected for the 1917-18 season. Six varieties of each of the five classes of Indian canes were chosen; to these were added six from the unclassified list, six thick cane varieties, the four wild Saccharums growing on the farm and six Madras seedlings, all of which were grown from sets. Owing to the poor growth of the thick canes, a further set of 24 stools were examined at the sugarcane plantation at Nellikuppam, these being all of the *Red Mauritius* variety, which was known to grow very well there under crop conditions. During this season 239 clumps, consisting of 629 plants, were dissected. The facts observed during the previous year were utilized for the preparation of a definite scheme of observations and measurements, the main purpose of which was the comparison of the branching systems of the different groups and the characters of the branches of different orders. In each plant dissected a diagram was prepared, in which the relative position of the branches was shown, and a formula was prepared, in algebraical form, of the constitution of the plant as far as matured canes were concerned. Besides this, all the canes were measured as to thickness and length of joints, and notes on runners, curvatures, injuries, etc., were recorded. The present paper seeks to extract the general principles of the branching of the sugarcane plant from this mass of material.

The following are briefly the results of this study. From the four months' dissections it is seen that the different varieties vary greatly in the rate of maturing and cane-formation, but this study is complicated by the fact that it was impossible to examine all the stools at the same time owing to the large number dissected, the time occupied in the work extending over six weeks. A series of tables have been prepared, from which it is not difficult to judge of the relative rate of maturing of the different varieties (*cf.* pp. 129–132a).

From the general formulæ of canes at harvest, obtained by averaging the dissections of all the plants of a variety, it is seen that the branching in the various groups, from the wild Saccharums to the thick tropical canes, is of the same nature, but of very different degree (*cf.* p. 116). Taking a to represent the main shoot, b its branches, c branches of b, that is of the second order, and so on, we get a series of formulæ of the canes at crop time, varying from $a + \mathrm{m}b + c$ in the thick canes, to $a + \mathrm{m}b + \mathrm{n}c + \mathrm{n}d + \mathrm{m}e + f$ in the wild Saccharums, and the different groups of Indian canes can be arranged in a series between these two extremes. It is hoped that a study of these formulæ

PLATE I.



Branches of different orders in the dissection of *Saccharum arundinaceum*, H2. The main stem, a, is in the centre, and bs, cs, ds, es, and fs are arranged on each side, passing outwards from the middle.

PLATE II.

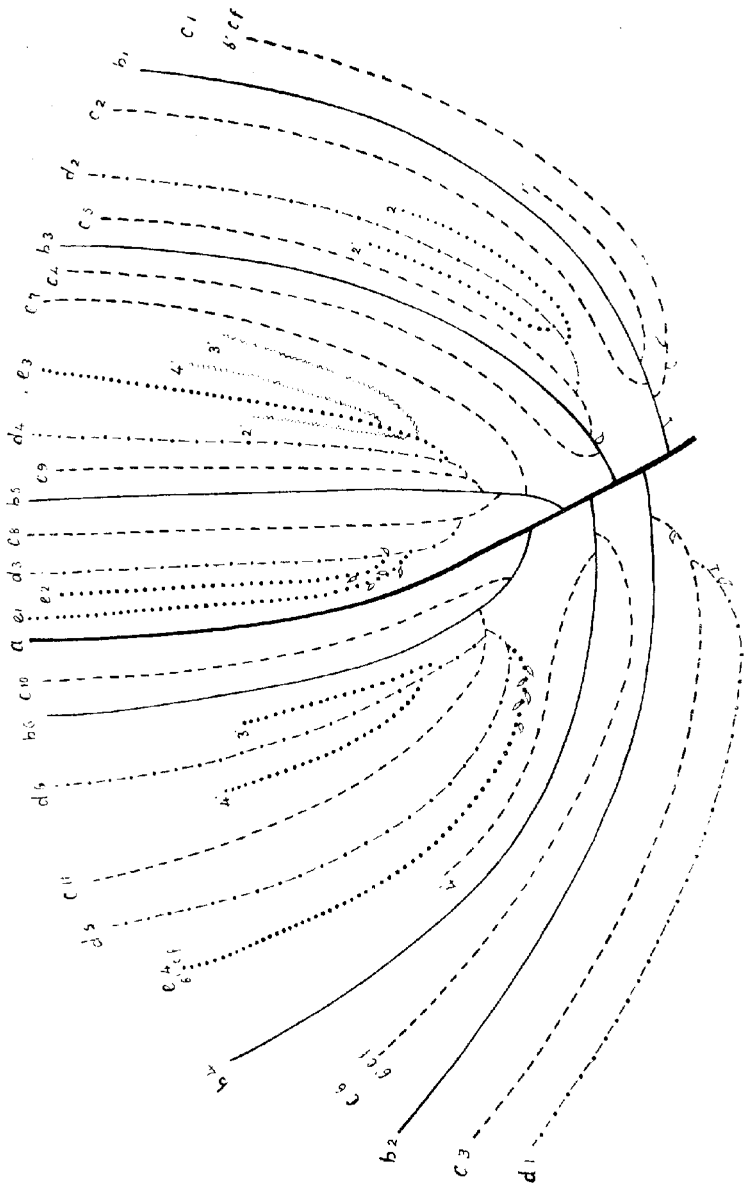


Diagram of the branching system in a plant of *Saccharum arundinaceum* (H2, of general list).

will throw some light on the stage of development of each group from its supposed wild ancestor.

The differences in form and size between the branches of different orders in the same plant have been carefully studied. Each cane has been measured as to the length of the basal, branching portion before it has assumed its full thickness, the thickness at two feet from the base, the average length of the joints in these two feet, the presence of curvature and runners, and so on. In all of these characters we find, as might have been expected, that there is a tardier development in the first shoot, and that this development increases in rapidity as the branches of the higher orders are reached. The general trend is for the branches of higher orders to be thicker, to have longer joints, and to show greater curvature. The main shoot has a longer basal, preparatory portion than its branches, but, when we pass to the other orders, the presence of basal curvatures, needed to place them in a position for upright growth, again increases the region of short joints at the base, for it is the general rule that a branch does not assume its full form until it is in a position to grow onward unimpeded. These details are all arranged in tabular form for the variety or group in the body of the Memoir (*cf.* Part III, Sections 4–6). In Memoir III, an example was given showing some of these characters, which was illustrated by plates. Here I add a more striking instance, namely, that of an ordinary plant of *Saccharum arundinaceum* (Pls. I and II), a species marked by its upright habit and symmetrical development, just as *Saccharum spontaneum* is by its intricate spreading growth. The diagram and detailed table of measurements are added, to give some idea of the character of the work done in each dissection undertaken. For further results, the reader is referred to the body of the work, as it is impossible adequately to summarize them without undue repetition.

The characters of the branches of different orders are seen to be so definite that, when a field is cut, we can without difficulty separate the canes at the mill into early and late. There is a good deal of similarity sometimes between the *a*s and *b*s, especially when the latter become facultative *a*s, but the change from *b*s to *c*s and *d*s is sufficiently striking to render their distinction generally very easy. This opens up a new line of work, in that it becomes possible to analyse these branches separately and to settle the question of their relative richness of juice and other qualities at the mill. Most of the work has, it is true, been conducted with Indian canes, and in one particular locality, but it seems unlikely that the thick canes will not fall into line, considering the general similarity of their branching system to that of Indian ones.

In the laborious work of dissection I desire to acknowledge my indebtedness to various members of my staff. At first all the dissections were done by myself, but I soon found that I was unable to cope with it, and interested my Assistant, M. R. Ry. T. S. Venkataraman, in the work and, later on, my second Botanical Assistant, M. R. Ry. U. Vittal Rao. With their help, I then trained two fieldmen, and the great mass of the later dissections were done by the latter under my personal supervision. In the first year, Fieldman G. V. James and, in the second, K. Rangaswami Pillai were engaged for months in the work, and I am greatly indebted to these officers for their care and intelligence. The selection in the field was entrusted to Fieldman R. Thomas, who had charge of rough cleaning and sending to the laboratory. The preparation of diagrams was mostly done by myself but, towards the end, here also I was able to leave it to Rangaswami Pillai. Several months were devoted to the work each year and, in 1917-18, it was found necessary to place three workers under the latter officer, who developed extraordinary neatness in his preparations. He was in entire charge of the work done on ***Red Mauritius*** canes at Nellikuppam. The shoot counting was under the direction of M. R. Ry. Venkataraman and chiefly done by R. Thomas and Plant Collector Abdul Sathar.

Measurements of Saccharum arundinaceum II 2, 1917-18.

(Extracted from the office files.)

NOTE. The development is fair, but not so mathematically arranged as in I 1.

Buds long, flat, hairy, scale like and not like the shooting buds of other varieties.

Formula. Canes at harvest : $a + 6b + 11c + 6d + 4e$.

Length of joints in the first 2′ and thickness at 2′ from the base. The first figure before the + is the length of the basal, preparatory portion of the cane, and consists of many short joints. (c, meaning curve, is inserted after the curve has finished.)

		Av. length of joint	Av. thickness in mm.
a	3¾, 1, 4½ + 1¼, 1¼, 1¼, 2, 2, 2½, 2½, 2¼, 3 ...	2·0″	154
b^1	2 + 1½, 2½, 2½, 3¼, 3¾, 3¾, 3¾, 3¾	3·1″	174
b^2	2¼ + 1½, 2¼, 3, 3½, 3½, 4, 4	3·1″	170
b^3	2½ + 1¾, 2¼, 3, 3¼, 3¾, 3½, 3½	3·0″	181
b^4	1¾ + 1, 2¼, 2¾, 2¾, 3½, 3½, 3½, 3½, 3 ..	2·9″	174
b^5	3½ + 1¾, 2, 2¼, 2½, 3, 3¼, 3, 3	2·6″	179

		Av. length of joint	Av. thickness in mm.
b^6	2½ + 2½, 3, 3¼, 3¼, 3¼, 3, 3½	3·1″	196
c^1	4 + 2 (curving round under b^1), 6½, 7, 7½	5·8″	242
c^2	1¾ + 4½ (straight from upper side of b^1), 6, 7, 8½	6·5″	192
c^3	2¼ + 3½, 4¼, 6½, 5½	4·9″	208
c^4	2½ + 2½, sl. c 5½, 5½, 6½, 6¾	5·4″	226
c^5	2 + 1½, sl. c 6¼, 5¾, 6½, 5¾	5·2″	222
c^6	3 + 5½, 8, 8¼ under	7·3″	(207)
c^7	3½ curve + 3, 4, 5¼, 6¼, 6½	5·0″	180
c^8	2 sl. c + 2, 5, 5½, 4¾	5·1″	206
c^9	2¼ sl. c + 3½, 4, 4½, 4¼, 4¾	4·2″	196
c^{10}	2¾ + 1¼, 2½, 2¾, sl. c 3¼, 5, 4½, 5¾	3·6″	202
c^{11}	3 + 4½, 6, 5½, 5¼	5·3″	221
d^1	3¼ v. sl. c + 3, 7, 8½, 8½	6·8″	232
d^2	2¾ + 4½, 7, 8¼, 8	6·9″	247
d^3	2½ + 3¼, 5, 6¼, 6¾	5·3″	255
d^4	2 + 2¼, sl. c 3½, 4, 5¾, 6¼	4·4″	235
d^5	2¾ sl. c + 5, 6, 6, 7½	6·1″	221
d^6	3 + 4½, 6½, 6½, 7¾	6·3″	249
e^1	4½ (curving under c^2) + 3½, 6¼, 8, 8¼	6·5″	223
e^2	3¼ sl. c + 5¼, 7¼, 7, 7¼	6·7″	232
e^3	3¼ curve + 5¼, 7¼, 7, 6½	6·5″	246
e^4	2 + 1¼, curve 5½, 7, 7½	5·3″	232

Summary of measurements of *Saccharum arundinaceum* II 2.

Formula of canes at harvest, $a + 6b + 11c + 6d + 4e$.

Shoots, $2c + 4e + 3f$. Burst buds, $1c + 3d + 2e + 9f$. Deaths, $1c + 1e$.

Average length of basal part, a* 3·7″, b 2·4″, c 2·7″, d 2·7″, e 3·2″.

Average length of joints in first 2′, a 2·0″, b 3·0″, c 5·3″, d 6·0″, e 6·2″.

Average thickness at 2′ (mm.), a 154, b 179, c 209, d 240, e 233.

Curving is absent in a and b, slight in c and d, moderately pronounced in e. There are no runners or injuries.

* The short-jointed, basal part is unusually long in a and consists of two sections, 3¾″ + 4½″ long, separated by one 1″ joint. The former figure only is taken here.

PART I. MORPHOLOGICAL CONSIDERATIONS.

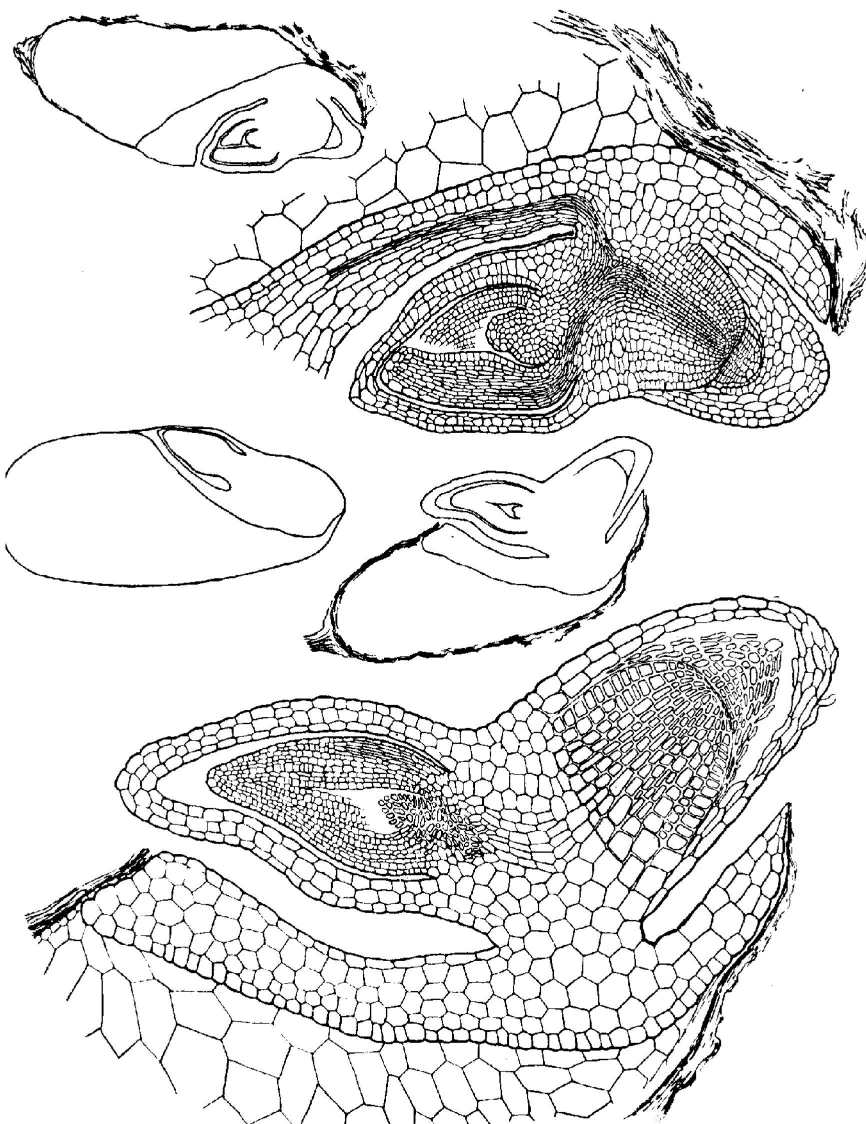
(1) EARLY STAGES OF SEEDLINGS AND SPROUTED CUTTINGS.

Before proceeding to the description of branching in the sugarcane, it will be advisable to get some idea as to the various stages by which the plant, as we see it, is built up. For this purpose, I have put together observations and drawings, which have been made at different times during the past five years, on the germination of the cane seed and the sprouting of the sets, as these will form a useful basis for our study.

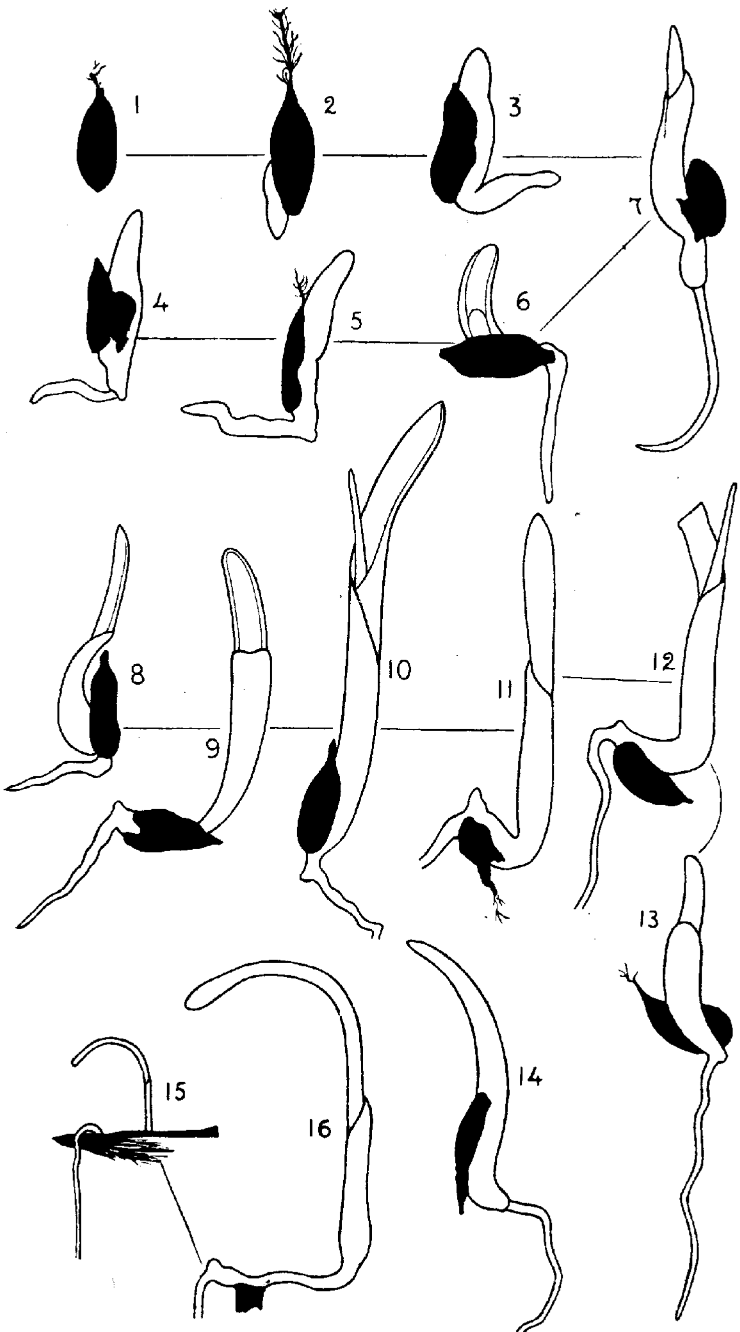
The seed of the sugarcane is extremely minute, the average length being 1·5 mm. and its breadth one-third of that amount. Strictly speaking, it is not merely a seed, but a fruit or caryopsis, for, as in all grasses, there is only one seed in the ovary, and its walls are fused with those of the fruit to an indistinguishable mass. The embryonic plant lies obliquely across one end of the seed, the rest being taken up by a mass of starch-bearing cells, the endosperm, a reserve of food for the early stages of growth. On comparing the relative sizes of germ and endosperm, the sugarcane appears to be poorly equipped with the latter, as, before the young plant protrudes from the seed-coats, it occupies in the vertical section nearly half of the space available. Considering the small size of the seed itself, there is thus very little food laid by for the initial stages of growth before it becomes independent; the cane seedling is excessively small and its growth is not nearly so rapid as the cultivated grains and, indeed, as the grass weeds which infest the seedling pans. The sugarcane in fact reminds us of the proverbial "mustard seed" in the smallness of its seed and the comparatively enormous size of the full grown plant. As a natural result of this, the seed of the sugarcane cannot be kept for long, although our series of observations, carried on for some years, show that its vitality is greater than previously supposed, and is not the same in all varieties (Mem. II, p. 127).

The general course of development may be gathered from the accompanying figures, firstly, of microtome sections through resting and germinating seeds (Pl. III), and, secondly, of drawings made from outside (Pls. IV, V and VI).

PLATE III.

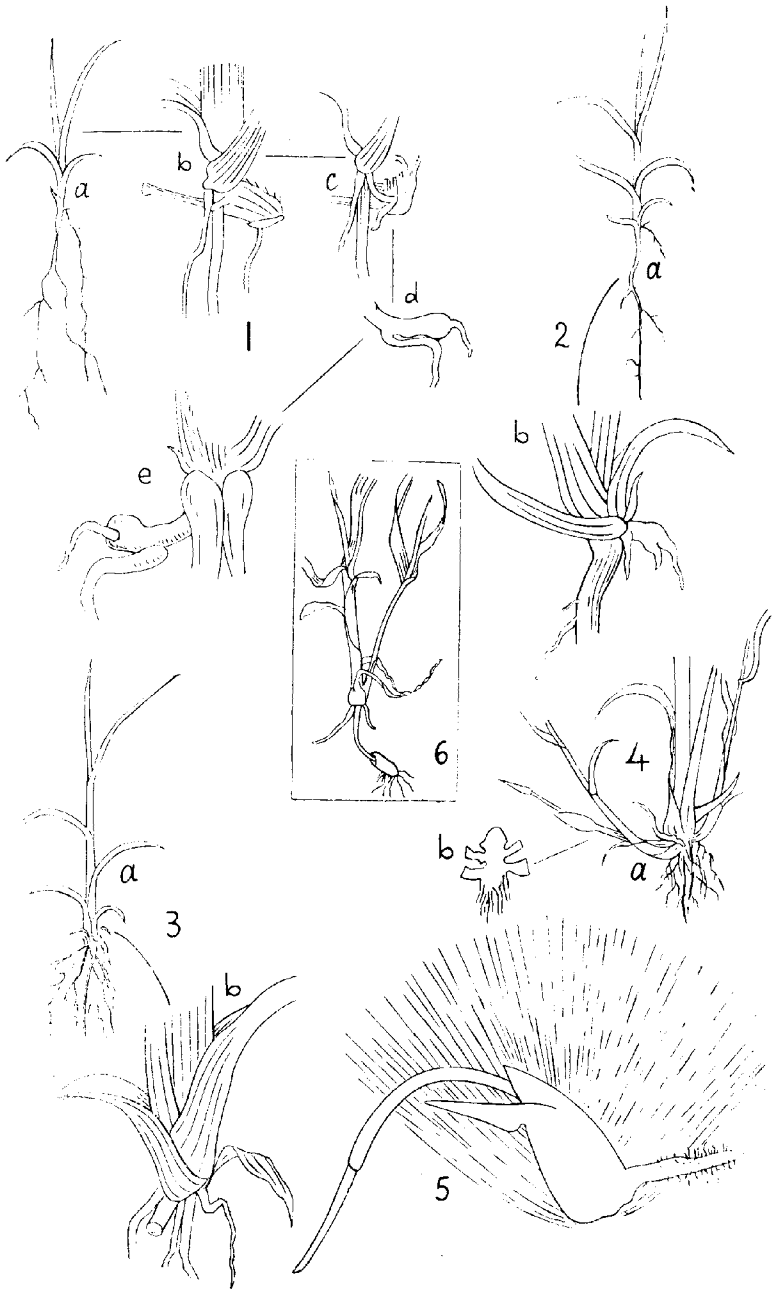


Microtome sections through resting and germinating seeds of sugarcane. Madras Seedling No. 6.



Germinating seedlings of *Kassoer*, figs. 1-7, four days old; figs. 8-13, eight days old: *Louisiana Purple*, fig. 14, six days old: *Madras Seedling* No. 2, figs. 15 and 16, thirteen days old.

PLATE V.



Young cane seedlings. Figs. 1-4, *Karun,* from one inch to one foot in heigt.
Fig. 5, germinating grass seedling. Fig. 6, young barley plant
(copied from Percival's ***Agricultural Botany***).

There is little in these Plates which calls for special attention, as the general course agrees with that in grasses and has been sufficiently described in text books. In the cases of *Karun* seedlings which have been examined (Pl. V.), there is an elongation of the plumule axis below the first leaf, similar to that in the wheat, presumably designed to place the young plant clear of its seed-coats and near to the surface of the ground for the purpose of tillering, and I have reproduced a drawing from Percival's *Agricultural Botany* to make this clearer. But, in the *Karun* seedlings, a thickish root is given off from this elongated part of the stem, which I have not seen figured elsewhere. The purpose of this early root formation appears to be obvious enough, namely, to reinforce at the earliest possible moment the small amount of available stored material at the disposal of the young plant. The radicle with its first root has, as usual, a merely temporary existence, or lingers for some time as a minute fibre which can have little effect in aiding the plant in its growth. After this preliminary arrangement of the parts of the seedling has been concluded, the plumule develops its leaves in rapid succession and, near their bases, a series of thick adventitious roots are soon produced ; but the seed-coats, with the plug-like sucker, the elongated plumule axis and its first adventitious root, remain attached to the plant for a considerable time, as they have been detected in a *Karun* seedling already five inches above ground. Different stages in this development are given on Plates IV, V and VI.

The leaves are formed in one plane, alternately on either side of the stem, and the whole young plant may thus be pressed flat with all its parts spread out. At a very early stage of development, a bud is formed in the axil of each leaf, so that the branches, as well as the leaves, all arise in the same plane. The formation of successive leaves, one at a time, has the effect of dividing the stem into a series of segments, each provided with one leaf and one bud. These segments are usually termed joints, and it is the practice to regard the joint as bearing its leaf and bud at its lower end, being thus terminated above and below by a leaf, and, when this has withered and fallen, by the sharp ridge or leaf scar which completely surrounds the stem. The region where the joints are separated is termed the node or knot, as it is usually more or less swollen, and the joint as defined above thus becomes the internode. An appropriate arrangement of the fibrovascular bundles within the stem has meantime taken place, and this can be very well seen in longitudinal sections ; namely, while the bundles run parallel with the length of the stem in the internode, they form an intricate, wefted mass at the node, and branches are given off to the leaves and roots at this point. This arrangement of the bundles takes place very early in the development, and it is thus easier to demonstrate

the limits of the first formed joints by viewing them in a longitudinal section than from the outside (Pl. VIII, fig. 1 c). The region of root formation is at the base of each joint, above the origin of the leaf, and consists of a narrow ring of the surface where the nascent roots may be seen as two or three rows of dots ; this is termed the root zone. In parts of the stem beneath the level of the ground these root primordia quickly grow out and, perferating the leaf bases, form a mass of roots which, with their branchings and root hairs, leave no particle of soil untapped. The first formed joints are extremely short, being in the form of narrow superposed discs, and the leaves borne by them are therefore very close together. The joints are, moreover, extremely thin at first, but increase in thickness upwards, the successive leaves and roots providing material for their expansion, so that, as in many Monolcotyedons, a longitudinal section of the stem at the base shows its form to be that of an inverted cone (Pl. VI, fig. 1 d). The leaves, growing much more rapidly than the stem, increase in width at the base and encircle a larger portion of the circumference of the stem until their edges overlap. The further development of the plant proceeds on strictly similar lines. The main points to be held in view are the upward increase in thickness of the stem, the protrusion of the buds from the leaf axils, the increasing number and thickness of the roots developed on successive joints, the continual lengthening and widening of the leaves, so as not only to completely encircle the stem, but also to enclose the younger parts in a set of enveloping sheaths, and, later on, the gradual lengthening of successive joints, so that the growing point is raised above the surface of the ground. Immediately this occurs, the stimulus of moisture and darkness being removed, the formation of roots falls into abeyance, but the root eyes can be detected in the root zone from the outside throughout the length of the plant. The leaf, at first purely protective and consisting of leaf base or leaf sheath, on emerging to the light, soon develops a small green tip, the leaf blade or lamina, and this part rapidly increases in relative size until it forms the bulk of the leaf. But this leaf development is much more rapid than that of the stem, so that, when the growing point of the stem at length reaches the surface, the leaves have already reached a very respectable size (Pl. V). The largest seedling (fig. 4) has a leaf already a foot in length, whereas the stem is as yet only one-third of an inch long.

The cane seedling four or five months old, viewed from above ground, usually shows a tall central shoot surrounded at its base by a number of smaller shoots emerging from the soil near it. These are the developed buds of the lower leaf axils. As the first joints of the stem are very close together, and each has its lateral branch, these shoots, being pushed out of their original plane

from lack of room, appear all together as an irregular circle round the main shoot, but careful dissection shows that they all arise from different axils on alternate sides of the plant (Pl. VI). The growth of successive buds, however, varies a good deal, and their size at this stage bears no sort of relation to the time at which they were formed at the apex of the stem. Some buds remain quite small during the life of the plant, whereas others grow so rapidly that they soon overtake or even exceed the main shoot in length.

The branches pass through exactly the same stages as the parent stem, only differing from it in that they have a better start and take less time to develop into leafy shoots. They are thin at the place of origin, bear closely packed leaves on the short congested joints, have a bud in the axil of each leaf, and, as the leaves increase in length and expand their blades, the stems increase in thickness, the successive joints become longer and the shoots as a whole emerge from the ground. As in the main shoot, the leaves at first grow much faster than the stem and, for a long time, the actual growing points of the stems remain below the ground, the height of the plant being judged by the length of the expanded leaves. This is readily explained by the fact that the growth of each shoot is largely dependent on the feeding power of its own leaves and, until these are fairly large, no real progress can be made, hence their early protrusion and proportionately rapid early growth. The relative size of the main shoot and its branches, and the number of the latter vary much in the same batch of seedlings, all stages being observable between one strong cane, with or without a few small shoots at its base, and a bunch of shoots resembling a tuft of grass, in which it is difficult to distinguish between the main stem and its branches (*cf.* Pls. XVI and XXIV of Memoir II, for illustrations of this). The reason for this is not clear, for seedlings thus differing in their early stages are often not distinguishable in their degree of branching later on.

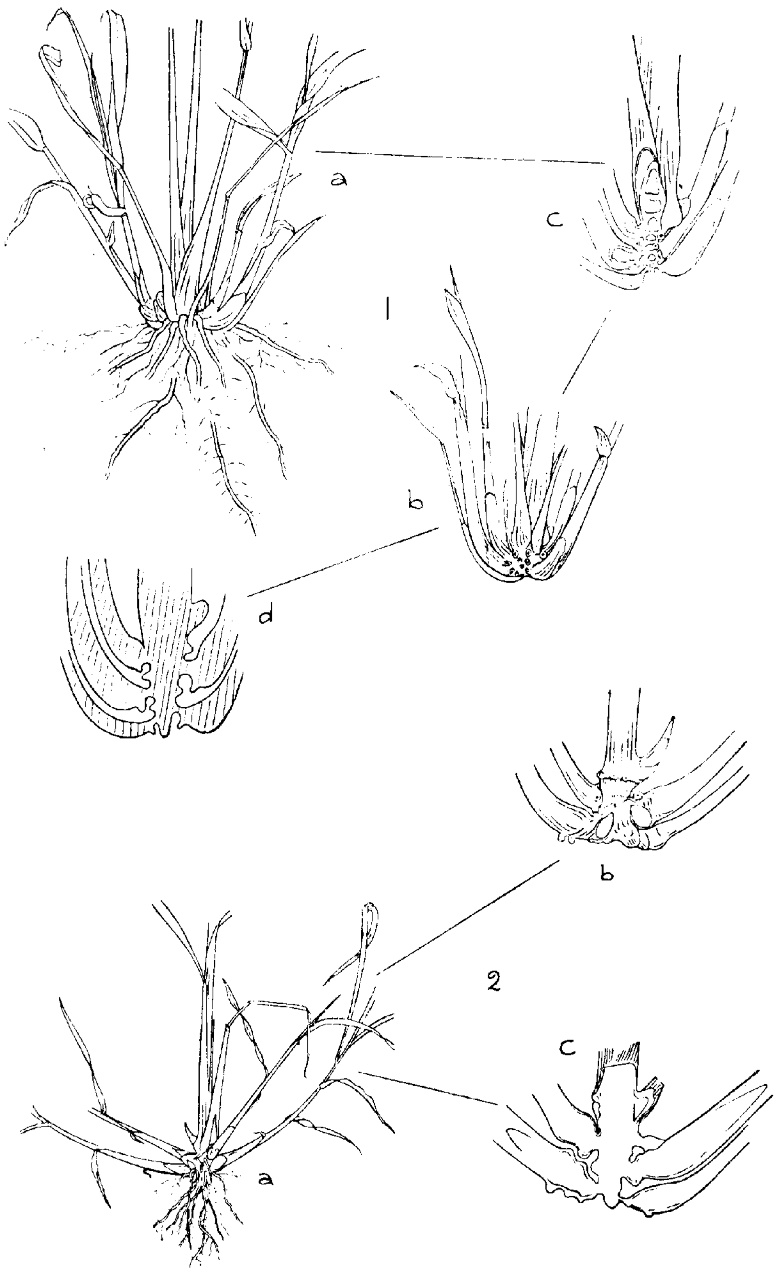
At a somewhat later stage, the lateral shoots, each as fully provided with buds as the parent stem, may also branch, giving rise to branches of the second degree, and this process may continue to several further degrees, this depending to a large extent on the parentage of the seedlings. Such shooting of the buds on lateral branches is not, however, usual until the plant has reached a further stage of development, unless, indeed, one of the branches receives an accidental injury low down, when its place is often taken by one of its uppermost buds. The chief points to bear in mind, concerning the branching of cane seedlings, are that every joint has its leaf and, protected by it, a bud, that both joint and bud have the power of forming independent roots if the necessity should arise, and that any of these buds may remain quiescent or

dormant throughout its life, or may shoot out at once or at a later stage in the growth of the plant as a whole. There is thus ample provision at hand for all the needs of the plant, whatever circumstances may arise. However severe the treatment above ground, there is a reserve of branches ready to be developed below, and, if one of the branches is either accidentally or purposely cut off, its place is taken by the emergence of one of its buds; and, if such a cut branch is placed in the ground, it is capable of sending out its roots under the stimulus of moisture and darkness, protruding its buds and developing into an independent plant.

Advantage has been taken of these facts in the planting of the sugarcane in the field. Cultivated sugarcane is propagated from cut pieces of the stem and is always likely to be. Seedlings, although undoubtedly a much cheaper form of reproduction, do not inherit the good qualities of their parents uniformly, and many of them, even of the best parentage, are quite worthless from the sugar producing point of view. Although extremely easily reared in many cases, they require more individual attention than is justified under crop conditions, and they take longer to mature. While in South India, canes grown from cuttings take, on the average, twelve months to mature, seedlings only become full grown when they are about eighteen months old. Besides this, there are many good kinds which do not produce seed at all, either because of infertility or the total absence of flowering. In vegetative reproduction the good qualities of the variety are rigidly handed down from generation to generation, although there appears to be a gradual diminution in vigour as the years pass.

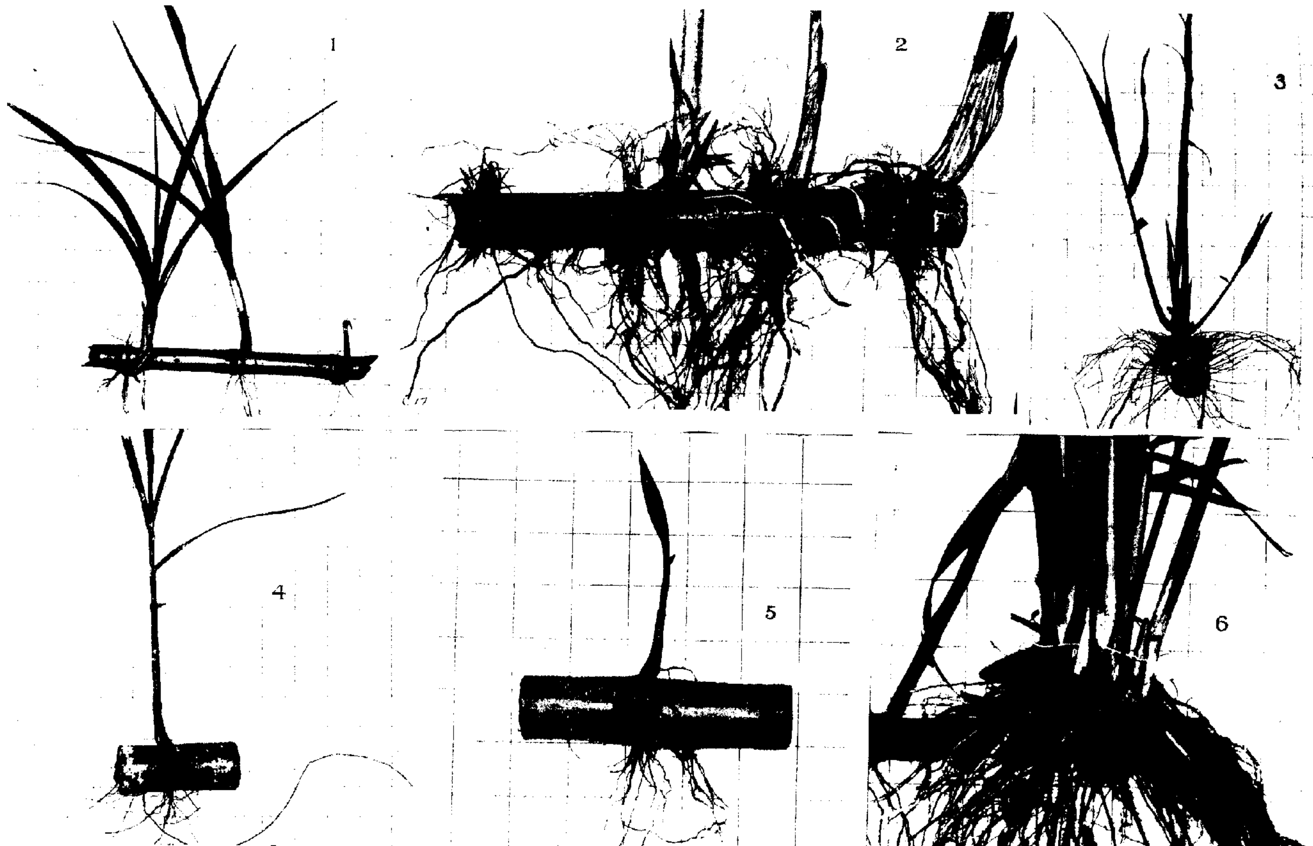
The vegetative method of reproduction is rendered easy, as explained above, in that each joint is furnished with its bud and a number of root primordia, and both of these require little stimulus to grow out. The condition of the bud may be compared with that of the germ in the seed, in that it is placed in immediate connection with a mass of readily assimilable nutriment in the joint to which it belongs. It is, however, much more fully developed than the germ, and it takes little time, under suitable conditions of moisture and warmth, for it to produce a mass of roots and leaves. The development of this bud need not detain us here. It is practically identical with that of the shoots described above, being merely a branch of the plant of a higher order. A series of stages are shown in Plates VII and VIII.

In planting, the whole cane is sometimes laid in a furrow, lightly covered with earth and watered; in many places, only the upper, immature parts of the cane are used and these, called "tops," are placed slanting in the ground;

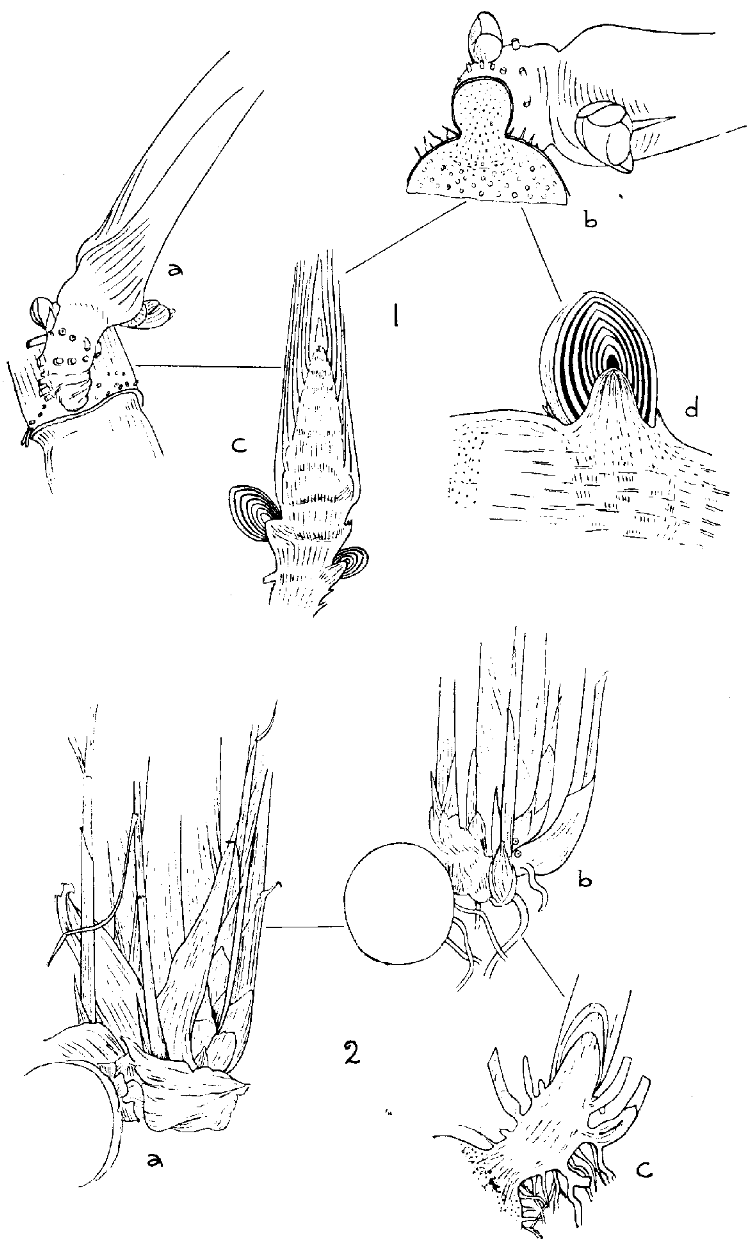


Cane seedlings about four months old. Fig. 1, *Poovan* seedling dissected (113 days old). Fig. 2, Seedling of *Saccharum spontaneum* (133 days old).

PLATE VII.



Sprouting set plants. Fig .1, *Saccharum arundinaceum*, showingbud beneath the set curving upwards and forming a healthy shoot. Fig. 2. *Gillman*, 25 days old. Fig. 3, *Red Mauritius*, 37 days old. Figs. 4 and 5, *Vellai*, 37 days old. Fig. 6, *Chin*, 50 days old.



Dissections of sprouting set pla:its. Fig. 1, *Gillman*, one month old.
Fig. 2, *Red Mauritius*, two months old.

but in India, as a rule, the whole cane is cut up into pieces called "sets," each of which has a definite number of joints with healthy living buds. Almost all canes germinate readily from sets, and, in India, they seem to produce healthier and stronger plants than the tops; but cases have been met with, as in *Seema* of the Godavari District, where sets are generally infertile and tops have to be used.[1] The sets in South India usually contain three joints; germination takes place more rapidly than in North India, and, if the field has not sprouted within a week or ten days, it is customary to plant again. In North India the climate at the time of planting is very cold and, not infrequently, a month elapses before the shoots appear above ground.

When, in a warm climate, the sets are placed horizontally in shallow trenches and watered, they at once send forth roots and the buds burst. Although, possibly, in ideal planting, it would be best to place the sets so that the bud plane lies parallel with the surface, this is not generally attended to nor essential, for the shoots are negatively geotropic and quickly find their way round the set to the surface of the ground.[2] The root eyes protrude and form a circlet of fibres round the set, those beneath growing much more strongly than those facing upwards, and these roots supply the stream of water which washes the nutriment stored in the joint to the developing bud. But very soon the lower joints of the new shoot form their own roots—thicker, whiter, and longer. When this occurs the shoot forms a new, independent plant, and the decayed joint from which it has arisen is left behind much as the cast off seed-coats in a germinated seedling. Connection with the plants developed from the other buds in the same set is thus entirely severed. Lateral branching takes place very early in the young plant, and these branches also produce their own roots, and, in a couple of months, the set plant has attained to the size and form of the six months seedling, and is growing much more rapidly.

The canes of different ages in the same clump are sometimes very different. This has been already noted in the remarks on early and late canes. But this difference is much greater in seedlings than in canes grown from cuttings.

[1] Barber, C. A. Scientific Report of the Samalkota Agricultural Station for the year ending 31st March, 1906. *Bulletin of Madras Agricultural Department*, 1907, p. 24.

[2] Since writing the above our attention has been drawn to the following. Kulkarni, in Dharwar, has made a series of experiments in planting sets, each with one bud only, and the set placed so that this bud is upward. He only allowed the mother shoot to grow and its branches were carefully removed. He claims that, by this means, sprouting takes place one week earlier, all the canes ripen together and a larger number are obtained per acre. (Kulkarni, M. L. Experiments in planting sugarcane sets with single eye-buds, etc. *Agr. Jnl., Ind.*, Special Science Congress Number, 1918.)

See also p. 102 and Plate VII, fig. 1 of this Memoir.

It is true that all the canes seem to be similar in some cases, but in others it is not unusual to note thin, yellow, sprawling canes developed first, these succeeded by reddish tinged slanting canes, while the latest formed are thick and dark purple ; and all sorts of such colour variations may be detected, as well as variations in thickness and erectness. We do not as yet know whether this variability is handed on to the next generation, when the seedling is grown vegetatively, or whether only one of the forms of cane noted is characteristic of the future crop cane, but experiments are being conducted to determine this point, which is of considerable moment for the proper selection of seedlings.

(2) Periods of growth.

The great bulk of the Order Gramineæ consists of grasses, and it will be of interest briefly to consider their mode of branching, in order to see in what respects the sugarcane resembles them—for the sugarcane has often been described as a gigantic grass. There are two well marked phases of development in grasses, the first, in which the plant remains low and adds shoot to shoot until a dense bush is formed, in which the shoots are often inextricably intertwined and point in all directions; and, the second, in which the ends of certain of these branches become erect, rapidly increase in length and proceed to form the spikes of flowers and ears of grain. In the first stage the energy of the plant is devoted to multiplying its number of shoots, chiefly by the branching of the underground portion ; in the second, branching ceases and the energy is diverted to pushing the branches high into the air and the formation of flowers where they can be readily fertilized, and seed where it can be scattered abroad.

In the sugarcane this division into periods of growth is to a certain extent hidden, in that, both in seedlings and set plants, each shoot, as soon as it is formed, pushes into the air and grows steadily upwards to form the aerial stem or cane. Flowering is a matter of secondary importance, and has largely fallen into desuetude from long propagation by the vegetative method. This is especially so in North India, where flowering is rare, but, in the Peninsula, as in most tropical countries, flowering takes place regularly towards the close of the growing season, and the fields then present a mass of feathery plumes over the whole area (*cf.* Pl. V, Memoir II). It may be noted, in passing, that the time of flowering does not coincide with that of reaping the crop, as these two periods are induced by very different climatic conditions. Flowering occurs at Coimbatore during the period of greatest rainfall in October and

November, and indeed seems to be greatly influenced in its profusion by the amount of rain falling during the year, while the cane is harvested when the juice is richest, and this occurs in February and March, after the cold season, when the air becomes hot and dry.

The formation of new shoots at the base of the cane plant proceeds during the whole of the growing period, but there is no doubt that it is much more active at the commencement of growth, for the rapid formation of canes is not really taken up until the plant is six or seven months old (*cf* p. 108). And this separation of the branching and lengthening periods of the plant is in certain cases emphasized by local conditions of growth. In South India the sets are planted at the commencement of the hot, dry weather, when the harvest is reaped, sugarcane being everywhere an irrigated crop. In the Godavari District, the young plants, after growing for a few months, receive a severe check, in that the irrigation channels are closed every year in May for cleaning, and, for some six weeks, irrigation is in abeyance, and the plants depend on such scanty showers as fall at this time. During this period, the branching of the underground parts goes on steadily, although little is added to the height of the plants. In fact the plants often appear to grow shorter, in that they are attacked by shoot-borer and many of the shoots are destroyed. But the ryot views the matter with equanimity, because he knows that this pest merely causes the lateral branches to be developed in larger numbers, and he asserts that he gets a better stand of canes when there is an attack of moth borer. It is probably of no great disadvantage for the shoots to be checked when there is no water to continue their growth; but cases are also met with where whole fields are destroyed by the pest, or ugly gaps are seen in the plantations. The branching period is lengthened and made more pronounced in this case which, in some respects, is analogous to winter-sown wheat in Europe.

A similar lengthening of the branching period is to be noted as the result of certain diseases of the cane. In the neighbourhood of Coimbatore, where many of the wells contain brackish water, sometimes the plants, especially ratoons, never reach the cane-forming period, but continue throughout the season to develop new shoots with narrow leaves, which do not grow in length but branch again, until, at crop time, nothing is seen but a number of low, dense, grassy bushes. A case was met with by the author on new, rough land, near the emergence of the Amravati river from the hills, where, in a couple of acres fourteen months old, only a few canes were observable, and the field closely resembled one of *Guinea grass*. It is needless to point out the similarity of this growth to that induced by *sereh* in Java and certain diseased

clumps observed years ago in Barbados, where all the buds and roots of the short canes shoot out, till a dense mass of grassy leaves is produced in place of a few tall healthy canes. (For an example of this kind of growth, see Pl. XII, fig. 1.)

Another feature in the branching of grasses may be noted here. It is usual to divide them, according to their mode of growth, into tufted grasses and sod-formers. In the latter, underground branching assumes an intense form, each bud piercing the base of its enveloping leaf sheath, and again branching itself, until, with the masses of roots formed at the bases of the joints, the soil is permeated so thoroughly that it can be cut into coherent slabs, as in lawns and permanent pastures. The individual plants are closely interlocked and it becomes very difficult to dissect them out without injury. The main feature in these grasses is the great development of underground runners or stolons, the ends of which emerge and bear tufts of leaves for the purpose of nutrition, while their place is taken by buds near the upward bend, and the underground part is thus formed of a mass of sympodia. Flowering takes place at a certain season, but this does not interfere with the underground branching. In the tufted grasses, on the other hand, after a limited period of underground branching, a number of erect shoots are formed which in due course proceed to the formation of flowers and grain. The buds in this case do not pierce the bases of the enclosing leaf sheaths, but grow up inside them, emerging where the sheath joins the lamina, only splitting the leaf sheath by their increase in thickness. The individual plants are easily separable, do not interlock, and each forms a more or less distinct tuft (*cf.* Percival, *Agricultural Botany*).

It is at once obvious that the sugarcane belongs to the latter class, as do the usual cultivated cereals. This also applies to the wild Saccharums, *Munja*, *Narenga*, *arundinaceum* and *spontaneum*, grown on the Cane-breeding Station. The two former are typical tufted grasses, no cane is formed and the flowering shoots are ephemeral structures, drying up after the seed is ripened. In *Saccharum arundinaceum* and *Saccharum spontaneum*, solid canes are formed. *Saccharum spontaneum*, although undoubtedly a tufted form, produces long underground shoots which emerge at intervals and thus spread the plant over a considerable area. It is difficult in growing this species, either from seed or from sets, to confine it to its bed, and the neighbouring paths are soon invaded. We may thus imagine an approach to the sod-former here. The nearest approach to sod-formation in *Saccharum spontaneum* which we have observed is on the banks of the Irrawaddy, where sandbanks are protected from being washed away by an interlacing mass of roots and runners, which forms a

solid cap a foot in thickness. The formation of underground runners is occasionally met with in cultivated canes. It is commonest in the Saretha group, the most primitive class of indigenous Indian canes, and, apparently, the nearest in descent to the wild *Saccharum spontaneum*. In other classes, runners are usually only formed where space is needed for the free development of a large number of cane stems. Thus we meet with them most frequently in the Mungo and Pansahi groups which are characterized by much branching. In these cases long, thin joints are intercalated between the normal short thick ones of commencing shoots, and in the dissections these are always noted (*cf.* also pp. 104 and 112).

(3) The branching of the cane above ground and abnormal bud formation.

Branching of the cane plant below ground is a well marked feature in all varieties. Above ground, in the light and in the absence of the stimulus of moisture, the buds usually remain inactive during the period of maximum growth. But the shooting of aerial buds is by no means uncommon, and is of some disadvantage from the crop point of view. It has been noted that some varieties, such, for instance, as *B. 208*, shoot more readily than others; but there are a number of circumstances which render all canes more or less liable to this defect. Any injury to a growing cane will tend to cause the buds below the injured place to shoot out because of the damming up of the current of water and nutrition. This is often seen where stem borer is at work. The joints immediately above the attack are shorter and thinner than the average, and large shoots are often observed coming from the nodes below the borer hole. Canes which have lodged or fallen will frequently develop a mass of shoots all along the prostrate part; over-ripe canes and such as have flowered usually form a mass of shoots in the upper part if allowed to continue growing; lastly, the local climate has a very distinct influence in the matter. Thus, when the same canes are grown at Pusa and at Coimbatore, they behave very differently as regards shooting. At Coimbatore, which is in a semi-arid region, shooting of the canes is very rare; while at Pusa, with its abundant supply of subsoil water, approaching the surface in the rains, a great mass of green is sometimes seen all the way up the stem, even in erect canes, long before the reaping season. This shooting of the buds is generally correlated with a more or less active protrusion of the root eyes. In places where there is a marked difference in the humidity and temperature at different periods of the cane's growth, this difference is often permanently marked on the different joints of the cane stem. Thus, at Rajshahi in North Bengal, it is easy at

2

crop time, to determine what joints had been formed during the hot, dry summer months, and at what stages the rains attained their maximum and ceased to flood the ground. The rooting and shooting of the canes in damp climates is often avoided by trashing, or pulling off the adherent but dying leaves, and it would be worth while considering the desirability of trashing canes in North India during the rains, in places where these defects are most marked.

Besides the normal branching of the cane, due to the protrusion of the ordinary buds on the joints, cases of abnormality are not infrequently met with, caused by irregularity in the bud development. Here and there canes have been met with where the joints have been altogether devoid of buds, and *Kaghze* has been marked in the Coimbatore collection as especially liable to this deformity. Here obviously no branching can take place. In others, double or triple buds have been met with in place of the single bud, and in the usual position. Where double buds occur, they are not infrequently the prelude to a dichotomous splitting of the cane into two equal halves, each then proceeding to grow normally. On passing down the stem, such double buds are seen to be preceded by buds of abnormal width, accompanied by a flattening of the stem (Pl. IX). Such cases have been very clearly described by Jeswiet,[1] and need not be further dealt with here. Among the cases of triple buds, one was noted as being extremely regular in its development, and it was preserved because of its interesting nature. After four years of reproduction the same abnormality can be seen, showing that it is a hereditable character of the seedling when propagated by cuttings.

But the most striking and frequent case of abnormal bud formation is when they are irregularly produced in different parts of the stem without any regard to the usual position. They are often met with in the root zone, for here there is, more or less permanently, meristematic tissue, but they may also appear at almost any part of the joint. They may arise direct from the outer layers of the stem, but more usually they are preceded by the formation of an irregular mass of callus, over which the buds are distributed unevenly, varying from mere pin points of tissue to fully formed buds with scaly leaves. Curious monstrous forms are thus produced, some of which have been selected for illustration on Plates X and XI. They would appear to be commoner on seedlings of certain parentage, although they have been found sporadically

[1] Jeswiet, J. Beschrijving der soorten van het suikerriet. Erste bijlage. Morphologie van het suikerriet. *Archief* v. d. *Suikerind. in Ned. Ind.*, Maart, 1916.

crop time, to determine what joints had been formed during the hot, dry summer months, and at what stages the rains attained their maximum and ceased to flood the ground. The rooting and shooting of the canes in damp climates is often avoided by trashing, or pulling off the adherent but dying leaves, and it would be worth while considering the desirability of trashing canes in North India during the rains, in places where these defects are most marked.

Besides the normal branching of the cane, due to the protrusion of the ordinary buds on the joints, cases of abnormality are not infrequently met with, caused by irregularity in the bud development. Here and there canes have been met with where the joints have been altogether devoid of buds, and *Kaghze* has been marked in the Coimbatore collection as especially liable to this deformity. Here obviously no branching can take place. In others, double or triple buds are formed in place of the single bud, and in the usual position. Where double buds occur, they are not infrequently the prelude to a dichotomous splitting of the cane into two equal halves, each then proceeding to grow normally. On passing down the stem, such double buds are seen to be preceded by buds of abnormal width, accompanied by a flattening of the stem (Pl. IX). Such cases have been clearly described by Jeswiet,[1] and need not be further dealt with here. Among the cases of triple buds, one was noted as being extremely regular in its development, and it was preserved because of its interesting nature. After four years of reproduction the same abnormality can be seen, showing that it is a heredit-able character of the seedling when propagated by cuttings.

But the most striking and frequent case of abnormal bud formation is when they are irregularly produced in different parts of the stem without any regard to the usual position. They are often met with in the root zone, for here there is, more or less permanently, meristematic tissue, but they may also appear at almost any part of the joint. They may arise direct from the outer layers of the stem, but more usually they are preceded by the formation of an irregular mass of callus, over which the buds are distributed unevenly, varying from mere pin points of tissue to fully formed buds with scaly leaves. Curious monstrous forms are thus produced, some of which have been selected for illustration on Plates X and XI. They would appear to be commoner on seedlings of certain parentage, although they have been found sporadically

[1] Jeswiet, J. Beschrijving der soorten van het suikerriet. Erste bijlage. Morphologie van het suikerriet. *Archief v. d. Suikerind. in Ned. Ind.*, Maart, 1916.

PLATE IX

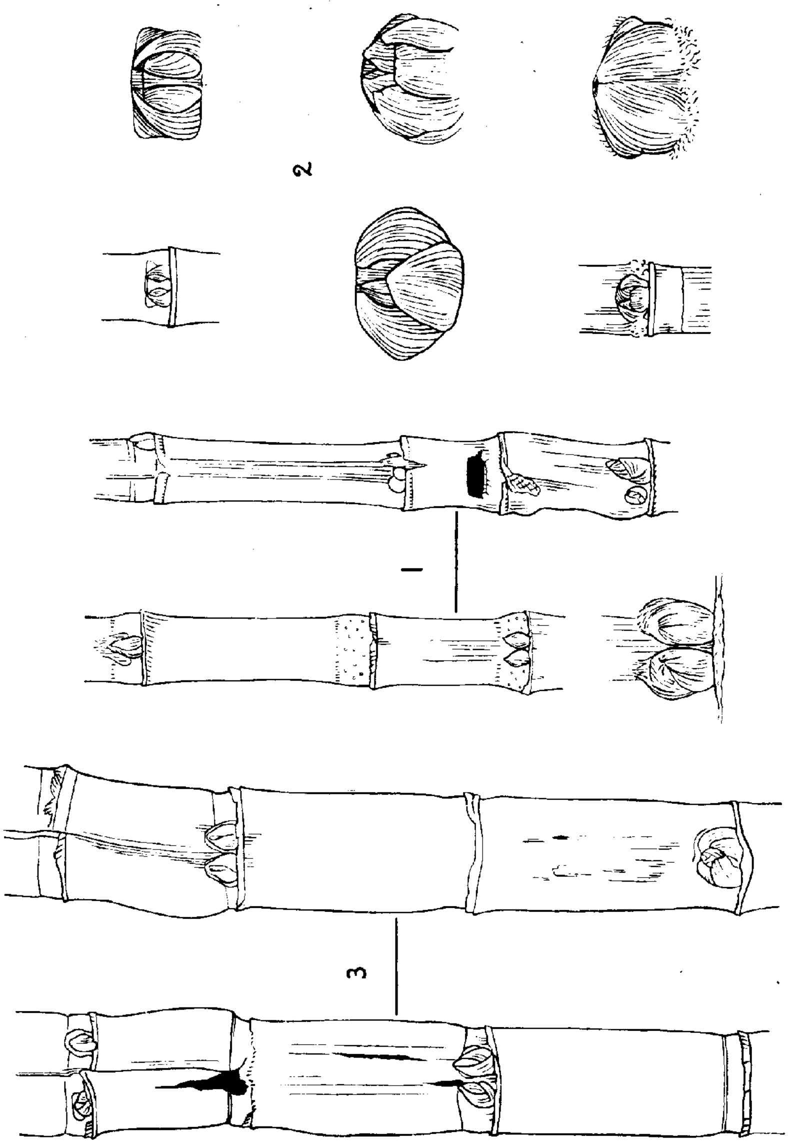
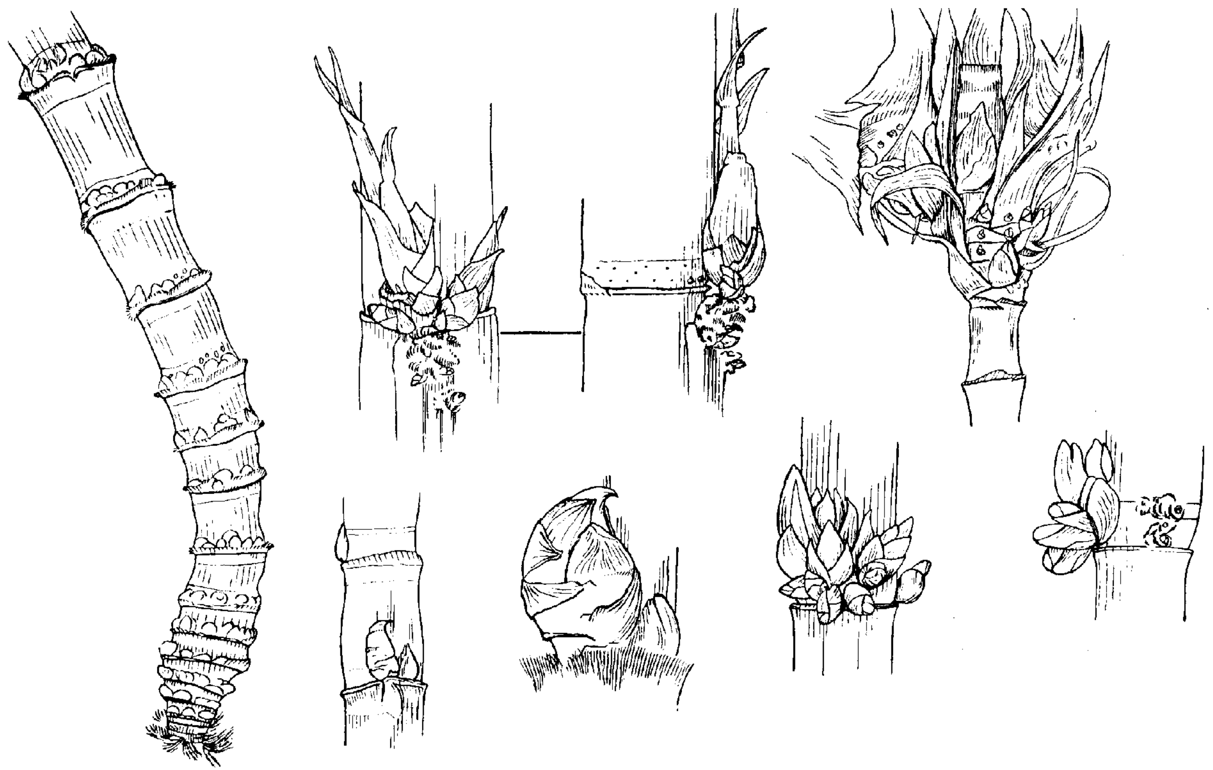
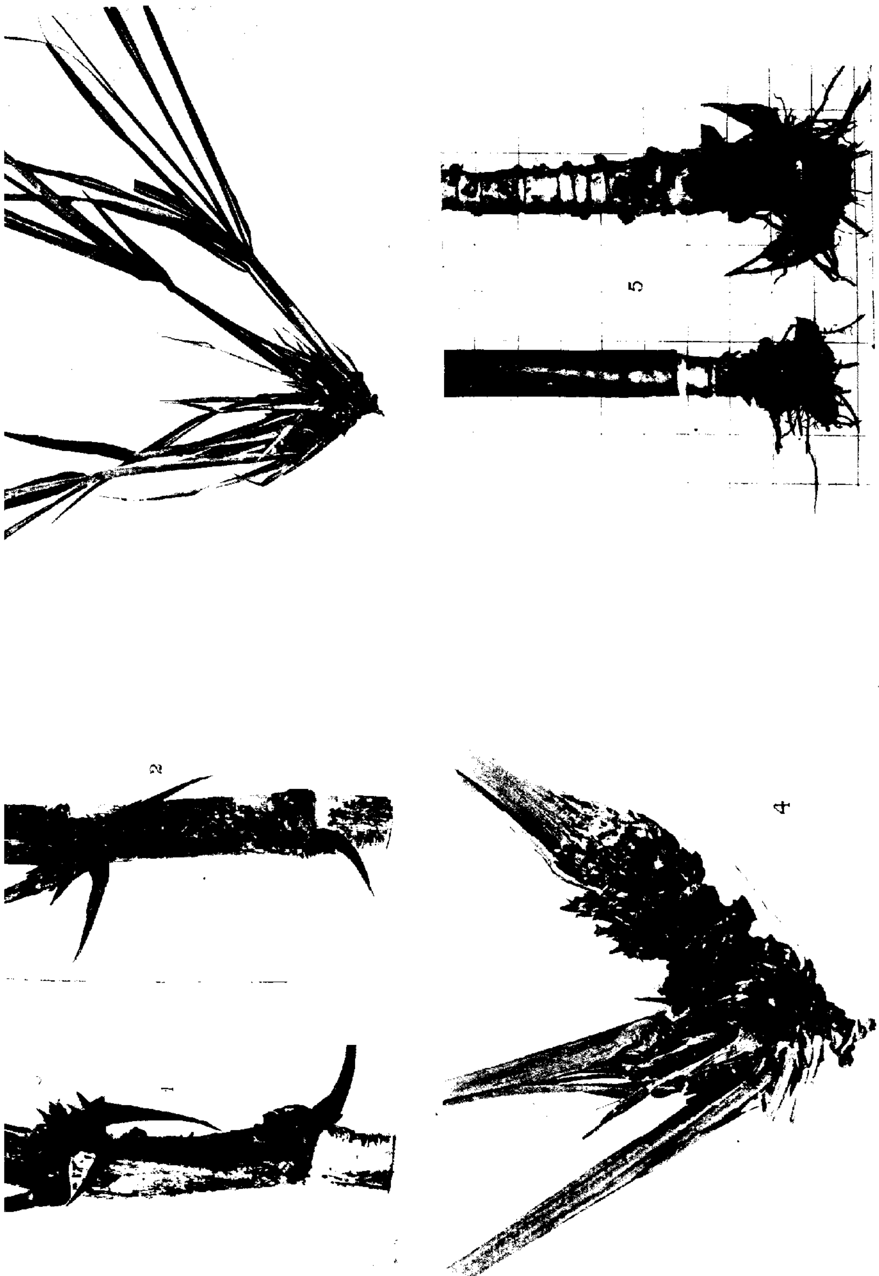


PLATE X.



Callus-formed buds and shoots. The multiplication of buds is usually confined to the root zone, but, in one case, a callus mass is spreading downwards from this region, and is developing buds at intervals.

PLATE XI.



Photographs of callus-formed buds and shoots.

Fig. 1, Grass-like cane plant, caused by abnormal shooting of all the buds. This is similar in form to plants attacked by various diseases, including *Sereh*.
Fig. 2, Canes suffering from "cuts".

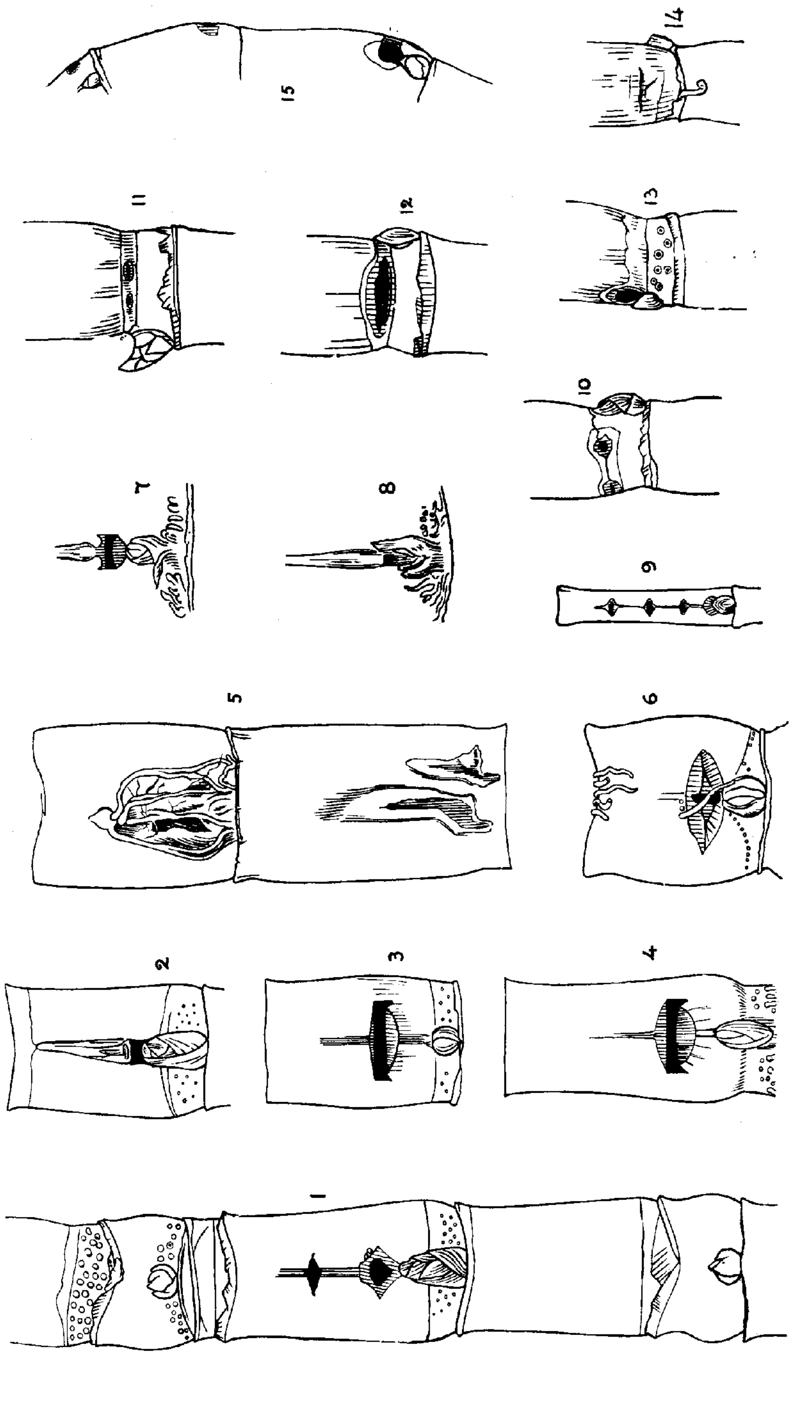
Explanation of Plate XIII.

"Cuts" and holes sometimes with callus formation. There is a marked tendency for the cuts to be formed in the groove above the bud. In many cases there is an upward continuation of the bud, above the cut, and this continuation is closely adpressed to the groove and fused to it for some distance (*cf.* figs. 2, 7 and 8). Callus is being formed in figs. 1 and 6 above the cut, and, in figs. 2 and 5, above a borer hole. In the latter case, an adventitious bud with roots is developing.

Fig. 9 shows the occurrence of cuts, in a simple form, on the stem of *Saccharum spontaneum*.

Figs. 10–15 exhibit the tendency for holes to be formed in the growth ring, and fig. 15 shows that this is specially common on the outer sides of curved canes.

PLATE XIII.



in almost all the plots, thus conveying the suggestion that the formation of cane plants from seed is no longer governed by the strict rules applicable to seed-bearing plants. In 1917-18 the *Khelia* plot of seedlings was thus marked out as containing numerous examples of this deformity. The cases thus far mentioned do not seem to have their origin in any injury to the cane tissues, but, in other cases, the callus results from the hole of a stem borer, the breaking of a cane, or the curious "cuts" above the bud in the groove, to which attention was drawn in the *Journal of Heredity* of February 1916. These cuts have been found in many of our seedlings and cane varieties on the farm, and appear not to be the result of any insect or other attack, but on differences in tension of the superficial layers of the stem. They have been found also in seedlings of *Saccharum spontaneum* in some quantity, and various cases have been drawn at intervals during the past five years. Some of these may be seen on Plates XII and XIII. A large number of other abnormalities have been noted in the seedlings and varieties grown on the station, and the study of these would undoubtedly prove of interest from the morphological point of view.

PART II. TILLERING.

(1) IN SEEDLINGS.

The tillering or branching of the cane differs considerably according to the variety, and, as the ultimate crop of canes produced is obviously influenced by this character, it is of some importance. Scattered through the literature of the sugarcane, there are to be found many countings of shoots at various stages of growth, as well as the numbers of canes reaped at harvest, and among the records on estates a far greater number probably exist. From these observations the tillering powers of the various canes under cultivation in different circumstances have been fairly accurately determined. But, when we attempt to draw conclusions from this material, we see that the subject has rarely been treated from a scientific point of view, and in almost every case there is an absence of the careful consideration of external factors which might be expected to have influence. We still wait for an exhaustive treatment of the subject with scientific safeguards. The present paper may be regarded as, in some sort, preparatory to such work being undertaken.

It will be well, in the first place, to consider exactly what the term implies. *Tiller* is an old English word allied to the *telgor* of the Anglo-Saxon, meaning a plant or shoot, and akin to the Dutch *telen*, to breed. At present it is, properly speaking, confined to the mode of branching characteristic of grasses. This consists in the multiplication of shoots, in the young plants, from the lower, short jointed portion of the stem, immediately below the surface of the ground. As we have noted elsewhere, this branching is the main work of the plant during its earlier period of growth. If the seed is sown too deep, one or more elongated internodes bring it to the surface, and then the joints become short and congested and branching commences (Pl. V, fig. 6). Shoots are not only given off by the main stem, but its branches may in their turn give off shoots, until a large number are produced. Branching in the upper, aerial part of the plant is less developed, occurs at a later period of growth and has nothing to do with tillering (*cf.* Percival, *Agricultural Botany*, where the matter is somewhat fully dealt with).

The factors influencing the amount of tillering in any plant are both inherent and external. Different species and varieties, as well as the seedlings raised in batches from the same parents, differ enormously in this character ;

but this difference is often cloaked by a number of surrounding circumstances, all of which seem to be translatable into the amount of food available, and of these, space, light, water, soil, and manure appear to be the most important.

We have followed the early stages of the sugarcane seedling somewhat carefully in a previous section, and it is at once evident that this mode of branching is present in it, and, therefore, that true tillering occurs in the sugarcane. We usually judge of the vigour of the cane seedlings grown at the Cane-breeding Station, by counting the numbers of canes and shoots at harvest time, and we thus have a certain amount of information as to the tillering capacity of the progeny of different parents, and the accompanying table gives a summary of these details. While examining the figures in this table, it will be well to note the spacing and rainfall for each year:

1911–13. Botanic Garden : plants 6′ apart, in pits measuring 3′ each way, filled with soil and manure : 1,200 per acre : rainfall 31·23.″

1912–14. Cane-breeding Station : fields 7, 8 and 9, sandy loam, but insufficiently prepared : 6′ apart, in pits measuring 2′ each way : 1,200 per acre : rainfall 21·08″. In this and the following cases the pits or trenches filled with prepared soil.

1913–15. Fields 10 and 11, clayey loam : 5′ apart, in pits measuring 2′ each way : 1,740 per acre : rainfall 36·49″ : canes counted at 14 months.

1914–16. Fields 15 and 16 and parts of 12 and 13, clayey loam : $4\frac{1}{2}' \times 5\frac{1}{2}'$ apart, in pits measuring $1\frac{1}{2}'$ each way : 1,740 per acre : rainfall 23·03″.

1915–17. Fields 17–20, clayey loam : planted in trenches $1' \times 1\frac{1}{2}'$, the plants $4' \times 5'$ apart : 1,921 per acre : rainfall 24·97″.

1916–18. Fields 10 and 11, clayey loam : trenches $1' \times 1\frac{1}{2}'$, the plants $4' \times 2\frac{3}{4}'$ apart : 3,760 per acre : rainfall 19·31″.

The 1911–13 plants were treated exceptionally well in their large pits of prepared earth, and the rainfall was good : the pits were smaller for the 1912-14 seedlings and the rainfall was meagre : the 1913–15 plants had the benefit of heavy, well distributed rain, but the rainfall for the 1914–16 plants was again meagre : in 1915-17 there was fair rain and the plants were 1,921 to the acre ; but in 1916–18 a marked drought occurred and the plants were nearly twice as close together. Taking the size of the pits or trenches filled with prepared earth together with the spacing, we see a continual narrowing of the limits of good soil in successive years. The rainfall was excessive in 1911-13 and 1913–15, extremely meagre in 1912–14 and 1916–18. In 1913–15 the cane counting was done later than usual.

Tillering of seedlings in successive years in the Cane-breeding Station.

Parentage	Seedling year	Number of lots	Number of seedlings	Average number of canes per seedling	Variations in averages of different lots	REMARKS
Thick canes ...	1912-14	4	862	14·5	One (13 plants) 11, the rest 13-15	
	1913-15	10	846	15·2	One (47) 26, the rest 13-16	The *Karun* lot (47 plants) showed unusual tillering and no explanation is recorded
	1914-16	4	963	14·6	One (241) 12, the rest 15-16	
	1915-17	9	521	13·5	One (72) 9, the rest 12-17	*Mauritius 55* seedlings (72) averaged 9 canes, *Naga B* (54) averaged 17
	1916-18	1	50	10·0	......	*J. 247*, a good tillering variety
Rogues among thick cane seedlings	1911-13	3	11	69·2	40-92	*Poovan, Namam, Kaludai Boothan*
	1912-14	2	2	97·5	55-140	*Karun* 55, *B. 208* 140
	1913-15	2	3	88·3	45-110	*Karun* 110, *B. 208* 45
	1914-16	2	17	56·1	56-69	*Ashy* and *Striped Mauritius*
	1915-17	6	11	46·6	18-85	
	1916-18	7	8	30·0	24-44	
Indigenous canes...	1911-13	1	19	48·0	......	*Cheni* alone 48
	1912-14	3	145	42·8	41-44	*Cheni* 44, *Saretha* (with shoots 52) 45
	1914-16	3	108	36·6	34-40	*Cheni* 35, *Saretha* 40, *Pansahi* 34
	1915-17	1	100	21·0	......	*Khelia* alone 21
	1916-18	4	304	18·5	17-21	*Pansahi* 18, *Khelia* 21
Crosses, thick canes by thick	1913-15	3	158	14·6	14-15	
	1916-18	1	132	7·0	......	*Vellai* × *J. 247*, a good tillering variety
Crosses, thick canes by thin	1913-15	3	54	22·0	18-24	
	1915-17	2	127	20·4	20-21	These are general collections from *Kaludai Boothan* and *Chittan*. The register says "probably crosses with *Naanal* seedlings," hence probably a mixture of crosses and selfs
	1916-18	9	956	12·8	10-15	
Crosses, thick × thin (*J. 213*), by thin	1916-18	3	441	17·9	17-19	*J. 213* selfed and unbagged crosses with thin canes: probably a mixture of selfed seedlings and crosses
Crosses, thick by *Saccharum Narenga*	1913-15	1	94	29·0	......	*Vellai* × *Saccharum Narenga*, a not very bushy form
Crosses, thin by *Saccharum spontaneum*	1912-14	1	62	81·0	......	*Saretha* × *Saccharum spontaneum*, both parents very bushy

Where comparisons are obtainable, the rainfall of 1913–15 appears to have made itself felt, and possibly the high rate of tillering of the *Karun* seedlings may have been partly influenced by it. The converse may be the case in 1916–18, a year of badly distributed and meagre rainfall. But the crop is plentifully irrigated and the influence of rainfall on the tillering is perhaps more apparent than real. The quantity of prepared earth and the spacing are much more likely to affect the tillering of the canes. This is quite obvious in the jumps from 1915–17 to 1916–18, but less so before that time. In the thick cane seedlings, indeed, there is little difference (15-13), but, where thin canes enter as parents, in part or whole, the decline in tillering is more marked, as it is also in the very aberrant rogues, formed among the thick cane seedlings. Rogues, 69, 97, 88, 56, 47, 30 : thin canes, 48, 43, 37, 21, 18 : *Cheni* 1911–13 (48), 1912–14 (44), 1914–16 (35), and so on. We are justified in concluding that the thick canes have been little inconvenienced by the narrowing of their limits in the field, owing possibly to the sparse nature of their branching; the thin canes, however, with their greater tillering power, have become considerably hampered in their development in the successive restrictions, in spite of the general improvement of the land since the farm was opened.

We can also see from the table that a study of the numbers of canes produced at crop time places in our hands a useful means of detecting whether an attempted cross between a thick and thin cane has succeeded, and we have become accustomed to use this character whenever in doubt on the subject (*cf.* Remarks on thick and thin canes in 1915–17 in the table). There is, generally, a constant increase in the numbers of canes as we proceed from pure blooded thick canes, through crosses between thick and thin, to such as have more thin than thick parentage and, finally, to such as have *Saccharum spontaneum* added.

(2) In cultivated canes.

With regard to the ordinary cane varieties planted from sets, it is well known that they differ a good deal in their amount of tillering. Thus the indigenous Indian canes tiller much more freely than the thicker canes of the tropics. This is the common experience of the Cane-breeding Station and, what is more, the descendants of these two classes of cane varieties inherit their parents' characters in this respect. Details regarding the Indian canes are few and far between. Practically the only comparative statement we have come across is one regarding canes grown at Sabour in Bihar.[1] In

[1] Woodhouse, Basu and Taylor. The distinguishing characters of sugarcanes cultivated at Sabour. *Mem. Dep. Agri., Ind., Bot. Ser.*, Vol. VII, No. 2, April, 1915.

this statement it is seen that the average number of canes per clump, in the thin Indian varieties grown there, is 8–16, in the half-thick forms (*Khelia*, *Striped Bansa*, *Puri* and *Sukli*) 7–8 (*Dahlsunder* 5·5), and in the thick, imported varieties, 4–6. It is not possible to deduce accurate acreage numbers from the table, because the details are not given of the space occupied by the clumps investigated. But the plants were put in at about 6,000 to the acre, and, assuming that the countings would not be taken where clumps had failed, as this would vitiate the results because of different spacing, we get, for the thin canes, 48,000–96,000 canes per acre, for the half-thick, 42,000–48,000, and, for the thick, 24,000—36,000. The latter figure tallies fairly well with those obtained for the cane varieties grown in the tropics. Numerous data can be obtained for these, and I have selected a few at haphazard from various sources.

Louisiana : *Purple* cane, 35,000.

Java : *Cheribon*, 20,000 ; *J. 247*, 31,500 ; *J. 36*, 32,000 ; *J. 100*, 28,600.

Madras (Godavari delta) : *Namalu*, 25,000 ; *Mogali*, 20,000 ; *Keli*, 31,000 ; *Seema*, 22,000 ; *Yerra*, 37,500, etc.

In almost all of these cases we note that, the thicker the cane, the fewer there are to the acre, and the general observation of this fact has led various writers to suggest that, given similar conditions of soil, climate and treatment, practically the same weight of cane may be reaped per acre whatever the variety may be. This principle appears to be fairly well established, provided that the cane varieties compared belong to the same natural class. A rather striking confirmation of this principle, that thickness and canes per acre are negatively correlated, may be seen in the following table, the details of which have been extracted from Memoir III, where the Saretha and Sunnabile groups of canes are contrasted (*cf.* pp. 166–167 and 169). These canes were all grown on adjacent plots under the same conditions.

Saretha Group			Sunnabile Group		
Variety	Canes per clump	Thickness in cm.	Variety	Canes per clump	Thickness in cm.
Chin	29	1·5	*Kaghze*	20	1·6
Saretha (green) ...	28	1·7	*Bansa*	18	1·8
Khari	24	1·8	*Sannabile* ...	17	1·9
Hullu Kabbu ..	22	1·9	*Naanal*	15	2·1
Ganda Cheni (poor)...	16	2·0	*Dhor* (poorly grown)	12	2·2
Average ...	24	1·8	Average ..	16	1·9

In this table the varieties of each group (all that were measured) are arranged in order of tillering power and, in the second column, where the

relative thickness of the canes is given, the order is seen to be exactly reversed. Too much weight must not of course be attached to this interesting result, for the relative differences are by no means proportional, and a comparison of the averages of the two groups is instructive as showing that the class of cane has influence; but a similar result, with many exceptions, is to be found in the longer tables appended, of thickness and tillering power of the varieties of the different groups in the 1917-18 crop on the Cane-breeding Station. Tillering and thickness of cane are inherent characters in each variety and group, but we must limit their correlation to the members of the same group. Thus, the Mungo class are among the thickest of the indigenous canes, being short and bush-like, and their tillering power is very great; on the other hand, the Nargori group contain, on the average, the thinnest Indian canes, and their tillering power is practically the same in the table as that in the Mungo class. Mere thickness cannot therefore be taken as a character from which tillering power can be deduced, but the group character must also be taken into account. In these and other comparisons, the thick canes, tropical, are generally taken as one class, because there is at present no classification prepared for them, as for the Indian canes. It is certain that great differences exist, which should be worked out in order to introduce a proper classification in them also. (See, however, Jeswiet's recent papers on this subject, where a series of descriptions of thick canes has been commenced. The inaugural paper has been referred to on page 56 above.)

Two tables are appended containing observations on the tillering of different Indian cane varieties during the 1917-18 crop season. The first of these contains observations and measurements made at my request by Mr. T. S. Venkataraman, during a tour in December and January last, when he visited a number of North Indian agricultural stations, where certain varieties were being grown, of which a series of measurements were desired for another piece of work. The chance of obtaining some idea of their tillering capacity was too good to be lost, but the observations were confined to the varieties being studied. These varieties were those also being grown on the Taliparamba and Samalkota farms in Madras, namely *Saretha*, *Chin* and *Khari* of the Saretha, *Pansahi* and *Chynia* of the Pansahi, *Baraukha* of the Nargori groups, and *Mungo* as representative of its own group. To these were added, where possible, one of the Sunnabile group, and, on account of the great similarity among themselves of the members of the Pansahi and Nargori groups, a certain amount of substitution was allowed in them where necessary. The observations were thus limited to certain varieties representing the different groups of indigenous canes, and are chiefly interesting as showing how greatly the same

canes vary in tillering capacity in different localities and under different conditions. First in importance of these conditions is the rate of sets planted per acre, but the general treatment, kind of soil, rainfall and irrigation also have influence, and notes on these are appended in the table. Making every allowance for these differing circumstances, we still see that the same cane differs much in its tillering power in different parts of the country, and, to make this more evident, a column has been inserted giving the numbers of canes per acre, in each case calculated from the number of sets sown per acre, and the average number of canes per clump. The figures in this column are not to be taken as an accurate estimate of canes per acre, in that they assume that every set grew into a plant, and that the part of the plot where the canes were counted was characteristic of the whole. The figures are of more use in comparing the relative branching of the canes in the different farms, than of the crops obtained. Taking this character of tillering as inherent in the variety, this variation is not surprising, for we have found similar differences to occur in almost every other character of the cane. The comparison of such other characters has been prosecuted for several years, and it is hoped will form the subject of another Memoir shortly. The length and thickness of the cane, the number of joints, the relative length of cane and shoot, the width and length of the leaf, the rate of maturing of the cane and the number of dead leaves adhering to the stem at different periods of growth, all of these characters have been found to vary profoundly, in the same cane, in different localities in India, and we have noted that the locality impresses itself on the plant produced to such an extent, that a survey of the series of measurements will generally enable us to determine in what part of the country the cane has been grown. A large number of deductions could be drawn from this table of tillering, but it is felt that these are foreign to our present purpose and, also, that the figures, having been obtained for one year only, require confirmation and extension, and it is hoped that this will be done by those in charge of the various farms. It may be noted in passing, however, that one of the most interesting results obtained is the way in which certain varieties seem to be adapted to certain localities, an aspect of the question which will be dealt with in the Memoir proposed.

The second table contains observations, also made at my request by Mr. T. S. Venkataraman, at crop time on the Cane-breeding Station, in April 1918. The cane plots on the farm are small, each consisting of one variety in three rows about 20 feet long. A space separates each plot from the rest in the form of a dropped row. For the tillering figures one row was selected in each plot, where possible the central one, but, where this had been used for other purposes,

an end row was taken and this is noted in the table. It was presumed that, because of greater space, there might be more canes in an end than in the central row, but this does not seem to be so to any great extent, and the position of the row may accordingly be neglected, as of little influence on the general results.

The number of clumps examined in these observations is therefore extremely limited, especially as the end clumps of each row, that is, those next to the irrigation channel and the drain at the other end, were excluded. The table is less to be relied on than the preceding one, but the general results agree well enough with those obtained on the farm in other years. The average thickness of the canes in the plot has been added, and this was computed from the average of 100 canes in each case. In this table, the varieties in each group are arranged in the order of greatest tillering. Comparing the average rates of tillering, we see that Mungo and Nargori groups head the list with 15·1 canes per clump; these are closely followed by the brown section of Saretha, then, in succession, the series of unclassed canes, Sunnabile group, Pansahi group and, last of all, the green section of the Saretha group, with 9·5 canes per clump. As regards thickness, Mungo heads the list and Nargori shows the thinnest canes. But both of these have the greatest tillering power, a fact that has already been commented on. The following summary table shows that, with the exception of Mungo and the green section of Saretha, the average thickness of the canes in a group varies more or less inversely with the rate of tillering.

Name of group	No. of varieties	Average thickness in cm.	Average No. of canes per clump
Mungo	32	2·60	15·10
Nargori	13	1·60	15·10
Saretha (brown)	13	1·62	14·00
Unclassified list	21	1·87	13·60
Sunnabile	22	1·90	12·55
Pansahi	17	1·95	11·00
Saretha (green)	10	1·86	9·50

Canes per clump and average thickness of canes in the varieties grown on the Cane-breeding Station, 1917-18.

	No. of clumps	Plot No.	Position of row	Av. thickness of cane in cm.	Av. No. of canes per clump
Mungo group					
Matna (Shahj.)	7	2641	end	1·70	24·6
Matna Ukh (Cawnpore)	7	2642	do.	1·95	22·7
Matki Mungo	7	2658	central	1·70	21·7
Kharwi	7	2656	do.	1·55	20·1
Reori	7	2644	do.	1·65	19·7
Matna (Aligarh)	7	2640	do.	1·85	19·0
Katara (Partabg.)	7	2648	end	2·10	18·7
Sarauti	7	2650	central	1·65	17·9
Lewari	7	2638	do.	2·05	17·9
Mungo (Sabour)	7	2626	end	2·25	17·6
Kuswar (Ottur)	7	2635	do.	2·25	17·1
Kuswar (Aligarh)	7	2636	central	2·35	15·6
Rheora	7	2643	do.	1·90	15·4
Patarki Mungo	7	2657	do.	2·10	15·1
Kuswar (Partabg.)	7	2637	do.	1·95	14·9
Mungo (Aligarh, Partabg.)	7	2627	do.	1·95	14·4
Khatuia	7	2645	end	2·20	14·1
Hemja (Bhikanpur)	7	2629	do.	2·30	13·9
Dark Pindaria	7	2655	central	1·60	13·7
Katara (Barah)	7	2647	end	2·20	13·6
Matanwar	7	2653	central	2·30	12·6
Paunri	7	2628	end	2·20	12·4
Agoule	7	2646	central	2·20	12·4
Burli	7	2633	end	2·15	12·1
Pararia	7	2652	central	2·15	12·0
Hemja (Sab. 2 E.)	7	2630	end	2·20	11·3
Poraya	7	2639	central	2·40	11·1
Hemja (Sab. 2 B.)	7	2631	end	2·30	11·0
Pararia	7	2651	central	2·15	10·7
White Pararia	7	2654	end	1·90	10·6
Buxaria	7	2632	central	2·20	9·4
Ramgol	7	2649	do.	2·30	9·0
32 Varieties	...	...	...	65·90	482·3
Average	...	...	...	2·06	15·1
Saretha (*Brown*)					
Raksi	7	2659	central	1·35	20·0
Ramui	7	2661	end	1·60	19·1
Lalri	7	2662	do.	1·55	16·1
Baroukha Ukh	7	2666	do.	1·70	15·9
Chunnee	7	2665	central	1·60	15·3
Burra Chunnee	7	2669	do.	1·70	14·3
Chin (Aligarh)	7	2663	do.	1·40	14·0
Saretha	7	2670	do.	1·85	13·0
Kansar	7	2667	end	1·75	12·9
Chynia	7	2668	do.	1·75	11·6
Katha	7	2660	central	1·45	11·6
Chin (Partabg.)	7	2664	do.	1·50	11·1
Saretha Desi	7	2671	do.	1·55	7·1
13 Varieties	...	...	...	21·05	182·0
Average	...	...	...	1·62	14·0

Canes per clump and average thickness of canes in the varieties grown on the Cane-breeding Station, 1917-18.

	No. of clumps	Plot No.	Position of row	Av. thickness of cane in cm.	Av. No. of canes per clump
Saretha (Green)					
Dhaur Saretha	7	2674	end	1·80	11·7
Khari (Jubbulpore)	7	2677	central	1·90	11·0
Mesangan	7	2672	do.	1·50	10·9
Hullu	7	2678	do.	2·00	10·6
Kalkya (Satara)	7	2650	do.	1·85	9·4
Jaganathia	7	2675	do.	1·90	9·0
Ganda Cheni	7	2679	do.	2·00	8·6
Kalkya (Dharwar)	7	2681	do.	2·10	8·3
Saretha	7	2673	do.	1·65	7·7
Khari (Sabour)	7	2676	do.	1·90	7·7
10 Varieties	...	...	...	18·60	94·9
Average	...	..	...	1·86	9·5
Sunnabile group					
Teru (Harchowal)	7	2683	central	1·40	26·0
Ketari (12 A Sab.)	7	2690	do.	1·60	21·4
Bansa (E 51 do.)	7	2692	end	1·55	18·3
Rakhra (Partabg.)	7	2684	central	1·60	16·1
Ekar	7	2686	do.	1·65	15·4
Dhaulu	7	2687	do.	1·55	14·7
Teru (Gurdaspur)	7	2682	do.	1·45	14·0
Ketari (20 E Sabour)	7	2691	do.	1·65	14·0
Rakhra (Shahj.)	7	2655	do.	1·70	13·9
Sunnabile (Jub.)	7	2696	do.	1·95	13·7
Bansi	7	2694	end	2·10	12·7
Kaghze (Pilibhit)	7	2689	central	1·70	12·6
Kaghze (Aligarh)	7	2688	do.	1·65	12·1
Sunnabile (Jub.)	7	2695	do.	2·10	11·4
Naanal	7	2700	do.	2·10	9·7
Khadya (Nasik)	7	2698	do.	2·15	9·1
Putli Khajee	7	2697	do.	2·25	9·1
Mojorah	7	2704	end	2·50	8·0
Khadya (Dharwar)...	7	2699	central	2·50	7·4
Hotte Cheni	7	2701	do.	2·40	6·7
Dhor	7	2702	end	2·35	5·6
21 Varieties	...	...	...	39·90	271·9
Average	...	...	...	1·90	12·95
Pansahi group					
Pansahi (E 57 Sab.)...	7	2717	central	2·00	12·6
Sada Khajee	7	2719	end	1·85	12·3
Kahu (Irrigated)	7	2712	central	1·95	12·3
Kahu (Rain-fed)	7	2713	end	1·85	12·1
Thin Moulmein	7	2072	central	2·00	12·1
Yuba (Natal)	7	2710	do.	1·95	12·1
Pansahi (E 58 Sab.)...	7	2718	end	2·00	12·0
Sanachi	7	2709	central	1·95	11·9
Ketari (20 A Sabour)	7	2705	end	2·01	11·7
Merthi	7	2707	central	2·00	11·6
Maneria (E 56 Sab.)	7	2716	do.	2·00	11·3
Lata	7	2714	do.	1·80	10·1
Dikchan	7	2708	do.	1·90	9·7
Bharanga	7	2720	do.	2·05	9·4
Ketari (20 H Sab.)	7	2706	do.	2·10	9·3
Maneria (E 55 Sab.)	7	2715	do.	2·00	9·1
Chynia (E 39 Sab.)	7	2711	do.	1·80	8·0
17 Varieties	...	...	...	33·20	187·6
Average	...	...	...	1·95	11·0

Canes per clump and average thickness of canes in the varieties grown on the Cane-breeding Station, 1917-18.

	No. of clumps	Plot No.	Position of row	Av. thickness of cane in cm.	Av. No. of canes per clump
Nargori group					
Agoule No. 2	8	2733	central	1·55	19·6
Baroukha (Pursa)	8	2725	end	1·55	19·1
Manga	8	2732	central	1·60	18·8
Nargori (15 D Sab.)...	8	2722	end	1·60	17·9
Kewali (15 G Sab.)	8	2724	do.	1·50	16·5
Mungo (Sic.)	8	2736	do.	1·65	15·9
Baroukha (Shahj.)	8	2727	do.	1·65	14·8
Reora	8	2737	central	1·50	14·8
Kewali (14 B Sab.)	8	2723	end	1·70	14·3
Nargori (15 B Sab.)...	8	2721	central	1·50	14·1
Kalari	8	2734	do.	1·55	14·1
Ketari (12 D Sab.)	8	2728	do.	1·65	13·5
Ketari (12 J Sab.)	8	2729	do.	1·60	13·5
Baroukha (13 A Sab.)	8	2726	end	1·65	13·1
Chynia (E 41 & 42 Sab.)	8	2730	do.	1·70	12·3
Sararoo	8	2731	central	1·60	12·3
Katai	8	2735	do.	1·65	12·1
17 Varieties	...	...	...	27·20	256·7
Average	...	...	...	1·60	15·1
Unclassified					
Dhaur (Aligarh)	8	2741	central	1·80	20·9
Shakarchynia	8	2758	end	1·80	19·4
Dhaulu (of Phillaur)	8	2739	do.	1·65	18·9
Bodi	8	2738	do.	1·75	18·6
Kinar	8	2745	central	1·65	16·1
Khagri (19 D Sab.)	8	2749	end	1·90	15·6
Kanara	8	2747	do.	1·75	15·3
Barhai (Jub., Gurdaspur)	8	2755	central	1·40	15·1
Barhai (Jub.)	8	2756	end	1·40	15·1
Kinar	8	2744	central	1·75	14·9
Betakali	8	2740	do.	2·30	13·4
Dhaur Kinar	8	2746	do.	1·70	12·8
Dhaura (Azimgarh, Gurdaspur) ...	8	2743	do.	2·00	12·6
Agol	8	2748	do.	1·85	12·1
Khagri (Dacca)	8	2750	end	1·90	11·3
Baroukha (Shahj.)	8	2757	do.	2·00	10·8
Dhaur (Shahj.)	8	2742	central	1·95	10·4
Ikri	8	2752	do.	2·30	9·7
Khagri (Rajshahi)	8	2751	do.	2·10	9·6
Khelia (E 54 Sab.)	8	2754	do.	2·20	8·0
Khelia (E 53 Sab.)	8	2753	do.	2·15	7·3
21 Varieties	...	...	...	39·30	287·9
Average	...	...	...	1·87	13·6

On studying the relation between thickness and rate of tillering in the varieties of each group, we must remember that the fewness of the clumps examined has much greater influence in the variety than in the whole group. We also note that in the Nargori and Pansahi varieties the thickness varies within very narrow limits, and it is not surprising that no correlation can be established. The green section of the Saretha group also shows no correlation,

but, in the rest, there is a marked tendency for the thinner forms to have greater branching. For safe deductions on this point, a much larger number of clumps must be available for examination.

(3) DEATHS DURING GROWTH AND THE PERIOD OF MAXIMUM TILLERING.

In considering these and other tables on the tillering power of different varieties of canes, founded on the number of canes produced at harvest, it is necessary again to sound a note of warning at the somewhat loose use of the term in general practice. The total number of canes at crop time is not in reality a safe guide to the shooting power, or tillering capacity in its narrower sense, because a large number of shoots die during the life of the plant. This is a necessary result of cultivation, where a tufted grass is forced to grow within narrow limits, so as to obtain as many matured stalks as possible. There is not room for the development of a number of the shoots formed and hence the mortality among them is very considerable. Stubbs,[1] in his careful experiments on the *Purple* and *Striped Louisiana* canes in 1894-95, calculated that the deaths of shoots during growth were 58·9 per cent. in 1894 and 53·9 per cent. in 1895. Muller von Czernicki, in Java, counted the number of shoots appearing above ground at varying periods between 60 and 150 days, and showed conclusively that the numbers were far greater at the earlier than the later period. Thus, in *Cheribon* 120–180 shoots were counted in different plots at 60 days from planting and only 60–70 at 150 days ; the figures for *J. 247* were 160–240 and 90–100, and, for *J. 100,* 100–170 and 82–86 respectively. Strüben, in a series of experiments on *J. 247*, found that the better grown plots in the first two or three months gave 300–400 shoots per row, in one case the number reaching 415, whereas at eight months all of the rows gave only about 110 shoots. No data are as yet available as to whether Indian canes suffer this great mortality during the earlier period of growth, but there is some reason to suspect, from shoot-counting observations, that it is a much less serious factor than in the thick canes, and further countings have been commenced to settle the question.

Another point to be held in view is the relative rate of germination and tillering in different varieties. This of course does not refer to the effect of cold and drought, as for instance in North India where the early growth is so much slower than in the Indian Peninsula, but only includes comparisons where the conditions are altogether as similar as it is possible to make them.

[1] References to these papers will be given later.

We find that there is a considerable variation in different canes in this respect, as can be readily demonstrated in comparing the Saretha and Sunnabile varieties on the Cane-breeding Station (*cf.* Mem. III, p. 149). Muller von Czernicki found in his shoot-counting experiments, that *Cheribon* reached its maximum number of shoots at 60 days from planting, *J. 100* at 90 days, while *J. 247*, although having more canes at harvest than either of the others, was slower and later in its early stages (*cf.* Pls. XIV and XV). In comparing the maximum number of shoots formed in any variety, it is not safe, then, to count the number of shoots in the plots at any one time, but the rate of development must be held in view, so as to get a true maximum for each variety, and from this to deduce the number of deaths occurring. For a time the numbers of shoots formed exceed the deaths and the total numbers steadily rise in the plots, but a period soon supervenes when there are many more deaths than new formations and, once this period has been reached, there is a continuous and great reduction in total numbers ; later on, a sort of equilibrium is reached, when the activity of fresh formation wanes and the shoots are of sufficient vigour and size to be able to maintain themselves and grow to maturity.

4) Artificial interference with tillering.

The great mortality of shoots during growth is obviously of serious import from the crop point of view. Not only is the possible number of canes diminished, but the formation of such numbers of abortive shoots must be a serious drain on the reserves of the plant. Attempts have accordingly been made from time to time to limit the tillering of the sugarcane by artificial means. It is the common practice with many crops to thin the plants out when they have become established, thus assuring a full stand with plenty of room for the development of each plant. This practice is hardly applicable to the present case, which is more analogous to the thinning out of branches in pruning and removing an excessive number of fruits or flowers for the better development of those that remain. Rosenfeld conducted some experiments at Tucuman on the effect of the thinning out of cane shoots on the crop, but found that the results from this procedure were rather adverse than otherwise.[1] These experiments, are however, open to serious criticism and cannot be regarded as demonstrating the inadvisability of the practice of thinning. His experiments were conducted on a single plot of canes, half of which was thinned

[1] Rosenfeld, A. H. Experiments in thinning out sugarcane rows. *International Sugar Journal*, 1914, p. 220, and 1918, p. 20.

and the other left intact. There was no control or duplicate plot. He repeated the thinning operation each year on the same plot, where the canes were grown, to first, second, third and fourth ratoons. It would be a mistake to assume that these successive experiments on the same plot were in any way a substitute for proper control plots, in that any fault in the original selection would but be repeated each year. Besides this, it is quite possible that ratoons may behave differently to plant canes in this matter, and also among themselves, whether first ratoons or those of a higher order. No hints are given as to the character of the season in each year, although there are intrinsic evidences that these differed, and it is quite reasonable to suppose that the thinning would have a different value according to the season, and consequent general health and growth of the plants. Lastly, no preliminary experiments appear to have been made at the correct time of thinning. The plot was planted in June, it was thinned in March "*where it was thought necessary*," "*by removing suckers and small canes where there was an abundance of larger better grown stalks*," and the crop was reaped in July. It would seem natural that this late removal of small canes would act prejudicially on the weight of the crop at harvest, and the canes were also naturally, on the average, thicker as well as fewer in the thinned plots. For a decisive result on the effect of thus artificially restraining tillering, the thinning should be carried out systematically throughout the plots, separate plots should be thinned at different periods of growth, and a reasonable number of controls should be introduced.

In Louisiana, profuse tillering is a matter of some moment because of the shortness of the season. For the best results to be obtained, it should be great in the earlier part and small or absent at the end of the season. This has been very clearly explained by Stubbs,[1] and a further danger in late tillering has been pointed out by him. Shoots developed after July 1 are not likely in Louisiana usually to mature before the cold weather sets in. Furthermore, late tillering and shooting of the aerial buds destroys the evenness of the stand in the ratoons of the following year, as these are (presumably) killed during the cold weather. Stubbs therefore paid very marked attention to the matter for several years, and adopted various methods which, he thought, might regulate the branching of the cane at different periods of growth, his desire being to stimulate the early and restrain late formation of branches. His general conclusions are summed up in the statement that tillering is a natural property of the cane and cannot be prevented. As the result of his experiments

[1] Stubbs, W. C. *Sugarcane*, Vol. I, Chapter XIV, Suckering of cane.

he, however, suggests that continued working between the rows without injuring the roots might act as a restraining influence on too late branching.

The earthing up of the cane rows is a well-known practice, both for the purpose of drainage and the provision of suitably prepared nutriment, and for giving the plants a firm hold on the ground when they are tall and stormy weather prevails. It is customary in Java for this operation to be performed at stated intervals, and there appear to be four successive earthings up, during the first four or five months of the plants' growth. This practice, as with all the agricultural operations on the cane field, is doubtless the result of numerous careful experiments during past years. From what we have stated regarding the different phases of growth in grasses, we should naturally assume that the heaping of earth over the base of the cane plant would, by lengthening the period of underground branching, tend to increase the tillering. But it seems to be held by many in Java that earthing up tends rather to restrain tillering. As, however, the opinions expressed from time to time have been very conflicting, Strüben[1] and others have conducted experiments to see if tillering was affected by delaying the earthing up. Strüben's general conclusion is that the time of earthing up has little or no effect on the general crop result. In another paper he deals with other matters, such as manuring and spacing, and comes to the same general negative result, and it is worth while drawing attention to the fact that he would almost seem to hold a brief for the non-effect of these various operations, whereas it occurs to us as quite possible that another worker might have come to a somewhat different conclusion on the facts quoted by him. We shall refer to this in more detail later on.

(5) On the factors influencing tillering.

Of all the factors influencing tillering, perhaps the most important is light, but the provision of other needs of the growing plant, such as warmth, moisture, soil constituents and manuring must also be considered. Lastly, the space available is of immediate effect, because of the interference of the shoots with one another and the varying amount of light and food in all its forms which may be obtainable. It should be obvious that tillering, being an essential characteristic of the growth of the plant, will be assisted by anything that induces a better physical condition.

The influence of *Light.* We have seen that deeply planted grass seedlings at once set about an attempt at reaching the proper place for tillering, near the

[1] Strüben, W. Vroege of late aanaarding? *Archief v. d. Suikerind. in Ned. Ind.*, Bijblad, 1909, p. 592.

surface of the soil. A similar contrivance has been shown to exist in certain young sugarcane seedlings (p. 47), but observations have not been recorded as to this habit in deeply planted sugarcane sets. In our dissections, however, we not infrequently meet with what might be termed upright runners, in which, long, thin internodes are intercalated between the usual, congested short internodes of the base, and doubtless the meaning of this is sometimes the same as that in seedlings, in that thereby the underground part may be placed in the best position for rapid branching, near the soil surface. Tillering cannot take place satisfactorily unless the shoots are able immediately to emerge into the light. But when a certain number of branches have been developed, and the light space so to speak is filled, further shoots are at a disadvantage in that they are overshadowed by their neighbours. This is undoubtedly the cause of the great mortality in cane shoots during the growth of the crop, and it is not easy to see how this perfectly natural effort at producing as many branches as possible can be prevented, if the plant itself has not the power to adapt itself to the conditions. It is fairly certain that this death of shoots is not due to the lack of food supply in the soil, for this can be and, habitually, is supplied to meet all possible needs. Generally speaking, all plants in the light branch more freely than in the shade. Growth in length is repressed in light and a more spreading habit is induced which gives room for more shoots to be developed. As one author has justly argued, of all the food producers on which the plant is dependent, light is the only one over which we have no control. There is a definite amount of light available for each area, and this we cannot increase by any means, whereas air is moving, and water and salts can be applied artificially. We can increase the depth of soil and the amount of water, can improve the physical condition of the soil and add manures as desired, but, as soon as the amount of light available is fully occupied, the further branches are shadowed and unhealthy, however many we may by various means cause to be developed. It is a common experience that trees on the outside of a forest, or in free space, are much larger and more uniformly developed than those within the forest, and this is not only due to their greater command of the soil around but also to the light available, and the same applies to cane plants near the edges of the fields or along the sides of the paths. The problem of obtaining the greatest number of canes per acre is thus seen to be strictly limited by this factor, as well as by those of cultivation and manuring. Light is perhaps the most important limiting factor as regards tillering.

Moisture also undoubtedly affects tillering, as can be seen by studying the plants along the irrigation channels where they are as closely planted as

elsewhere. The frequent advantage of plants so situated should be carefully noted, as suggesting that full use is not always being made of watering facilities. There is still a good deal of work to be done with regard to the effect of the duty of water on the number of canes to be obtained under varying conditions of soil and manuring.

Manuring naturally has its effect on the number of canes produced as well as their individual weight and the richness of their juice. A careful study of this effect has been made by Kilian, who desired to know the best manures to be applied to the three cane varieties which appeared to be suited to the different soils in his estate at Poerwodadi in Java.[1] Although his research was limited to a purely utilitarian problem, the care with which his experiments were conducted renders them valuable from the scientific point of view, and their limited range is of no disadvantage in this respect. The experiments were with *Black Cheribon* and *J. 247*, which were canes growing well in his conditions, and consisted of a series of plots to which were added varying amounts of sulphate of ammonia, superphosphate and cattle manure. Besides studying general yield and other matters, he counted the number of canes at harvest, and this renders his paper of interest to us. Briefly the results were as follows :—

In *Black Cheribon*, with the same amount of sulphate of ammonia, increasing doses of superphosphate gave a gradual rise in the weight of cane and of sugar per acre ; also there was an increase in the number of canes, but this was less regularly the case. With increasing doses of sulphate of ammonia, the numbers of the canes varied irregularly, whereas the weight of canes and of sugar gradually increased. With the addition of a suitable amount of cattle manure to a moderate amount of both of these artificial manures, there was a distinct rise in the numbers of canes in the plots, as well as weight of cane and of sugar at crop time. The experiments with *J. 247* seem to have been confined to the ammonium sulphate series, and the results were similar to those with *Black Cheribon.*

These experiments were carried out on soils varying from heavy black clay to thin dry loam, and we see that the addition of quantities of suitable manure, especially cattle manure, lead to a distinct increase in the number of canes. It seems probable that similar results would be obtained in other places, once it is determined in what direction the manurial constituents of

[1] Kilian, J. Bemestings-en plantverband-proeven op de S. F. Kanigoro, oogst 1908-9. *Archief* v. d. *Suikerind. in Ned. Ind.*, Vol. XVIII, p. 566, 1910.

the soil are lacking. Kilian's results on the numbers of canes are summarized in the following table:—

Numbers of canes per bouw ($1\frac{3}{4}$ *acres*) *with different manures.*

Experiments with super and cattle manure: *Black Cheribon*					Experiments with sulphate of ammonia and cattle manure on dry loam		
Manure	Thin dry loam	Dry loam	Heavy black clay		Manure	*J. 247*	*Cheribon*
4 pik. sulph. am. ...	33,011 slight fall*	38,261	28,772		3 pik. sulph. am.		
do. +1 pik. super.			34,367 slight rise	39,204 irregular	4 do.	57,135 irregular	34,559 irregular
do. +2 do.	36,045 rise				5 do.		
do. +3 do.		40,562			6 do.		
do. + cattle manure	37,698		26,612	42,865	4 do. + cattle manure	60,934	35,177

* The words "slight fall," "rise," etc., below an average figure, indicate any changes within the bracketed treatments.

Kobus[1] in an earlier paper (1905) describes the results of his experiments on growing cane uninterruptedly on the same land for a succession of years, with a various assortment of manures designed to take the place of rotation and fallowing. In this series were N, N and P, N and K, N, K and P, and all these with or without the previous addition of Ca. The series is a very full one, as it deals with three different varieties of cane, *J. 247*, *J. 33a* and *J. 36*. He states that the plots were much affected by the weather, there being a severe drought in the earlier part of the season, but that they recovered much better than he had expected. There were, however, many failures in germination, varying from 6·4 per cent. to 12·4 per cent. in the different varieties. Rats invaded the plots and created great havoc, to an extent in some cases of 40 per cent. Lastly, *J. 36* suffered from red rot, as this variety is more liable to the disease than the others. Among other data, he obtained the number of canes in each plot, and his general conclusions were that tillering is comparatively unaffected by manuring. By this we presume that he means rather that the *kind of artificial manure applied*, whether nitrogen, potassium, phosphorus or calcium in their various combinations, has little effect on the number of canes produced per acre. This does not seem to be quite the same

[1] Kobus, J. D. Cultuur van suikerriet zonder tusschen-gewassen. *Archief* v. d. *Java, Suikerind.*, Vol. XIII, 1905, p. 485.

position as that taken up by Kilian and, for the present, his more special work seems to be more to the point, as it deals rather with the quantity of suitable manure than the kind of manure applied.

Strüben,[1] in 1911, asserts that there appear to be no definite experiments on the effect of manuring on tillering. This seems rather strange, in view of his later quoting from both Kobus and Kilian. He states that he has often noted that very heavy manuring does not usually increase the number of canes. His general conclusion is that manuring does not affect tillering, although he does not himself experiment in the matter. As we have pointed out above, Strüben assumes the attitude that no appreciable alteration is made in tillering by various changes in cultivation, whether spacing, earthing up or manuring, and for this dictum he seems to depend on a generalization of Kobus, made in his 1905 paper, referred to above, that " with a difference of even 10 per cent. in the numbers of canes in a plot, there *may* be a similar out-turn of sugar at crop time." This perhaps will throw light on Strüben's attitude and, when he asserts that the number of canes is not influenced by manuring, he may mean that, as far as total sugar obtained is concerned, such differences as are noticeable are of little consequence. With this aspect we are at present not concerned, and have little hesitation in concluding that manuring has an influence on tillering, as well as any other means by which the healthiness and vigour of the plant is enhanced.

(6) Literature concerning the effect of spacing on tillering and on other crop characters.

The most obvious way of regulating the number of canes produced at harvest time is by varying the number of sets planted per acre. Spacing experiments have been conducted wherever the sugarcane has been cultivated, for the seed material, in many cases obtained by cutting up canes perfectly fitted for passing through the mill, costs a good deal and figures largely in the balance sheet. In some countries only tops are planted, namely, the upper, immature parts of the plant where there is no sugar, and the canes harvested produce these in sufficient numbers to plant up the new fields; but, in other places, tops are not available, as they form a valuable cattle food and, in India, for instance, are often the perquisite of the men from whom the cattle are hired for crushing the canes. We have already referred to the curious fact that, even in India, there are varieties which cannot be successfully

[1] Strüben, W. Uitstoeling. *Archief* v. d. *Suikerind. in Ned. Ind.*, Vol. XIX, Part 1, 1911, p. 487.

reproduced from the matured cane sets, but such exceptions are comparatively rare. When the Samalkota farm was started in the Godavari District, it was the local practice to plant 25,000 to 30,000 sets per acre, and the cultivators were quite content to put aside Rs. 30 to Rs. 40 for the purchase of seed per acre. A series of experiments was therefore initiated with the number of sets planted, varying from 4,000 to 30,000 per acre. The numbers of canes produced at harvest were counted and the amount of *jaggery* produced was estimated. These figures are now unfortunately lost, but the general conclusion arrived at was that, with proper treatment, each piece of land would produce the same weight of canes within comparatively wide limits, but that, when thick canes were sown at the rate of 12,000 sets to the acre, the maximum yield might be counted on, and that closer planting merely led to unnecessary expense in the purchase of sets. A similar series of experiments was made with *Reora of Benares* in Partabgarh in North India,[1] varying numbers of sets being planted per acre and the resulting yield of *gur* compared. Here, too, 12,000 sets per acre were found to produce the most satisfactory results, and the larger number of sets usually planted by the ryots did not give any increased yield. At first it strikes one as rather curious that thick and thin varieties, with their greatly differing tillering power, would require the same amount of space for their best development. But it must be remembered that the number of buds per set was considerably greater in *Reora* because of its short-jointed character. The number of sets planted per acre on different farms in North India appears, however, to differ very considerably (*cf.* Table on p. 63*a*), and it is not known whether these numbers are the result of series of spacing experiments, such as those made at Samalkota and Partabgarh, or are merely an adoption of the local ryots' practice until such experiments can be conducted.

Stubbs[2] quotes a certain Mr. Skeete, who speaks of sets planted six feet apart, with the result that often 50–100 canes were reaped from one hole. We have been unable to verify this reference or to discover what country is spoken of, but it appears to be not at all unlikely, for Prinsen Geerligs[3] states, of San Domingo, in the West Indies, that the canes are occasionally planted nine feet apart each way, which would mean only 538 sets to the acre, and presumably the tillering in such cases would be great enough to make up the requisite number of canes at harvest time. It is the custom at the

[1] Clarke, Annett and Hussain, etc. Experiments on the cultivation of sugarcane at the Partabgarh Experimental Station, 1910-11. *Bulletin No. 27, Agr. Res. Inst., Pusa*, 1911.

[2] *Ibid*, p. 95.

[3] Geerligs, H. C. Prinsen. *The World's Cane Sugar Industry, Past and Pres.*, p. 193, 1912.

Cane-breeding Station to give the thick canes more room than the thin, in spite of their smaller tillering power, and this appears to be the general rule in India where these two types of canes are planted on the same farm. There is, however, a much more liberal application of manure in the former case, for the thin canes are found to be unable to assimilate such heavy dressings and, at the same time, to mature properly at harvest time. The object aimed at in each case is to obtain a full stand, with as great a weight of canes as possible, without unnecessary expenditure in costly seed material. The development of the cane clump is influenced by warmth, moisture, soil, and no strict rule can be laid down as to the most suitable spacing, and hence the importance of the very numerous experiments which have been made.

Several workers have dealt fairly fully with the relation between spacing and the number of canes reaped, and it will be necessary to consider their papers somewhat in detail. As other matters, besides the influence on tillering, are also included in them, it will be convenient to treat these papers as a whole, and append a summary of conclusions at the end under the several headings.

Stubbs, in 1892-93, conducted experiments with the local Louisiana canes by planting the sets at distances of 6″, 12″ and 18″ in rows five feet apart. The plants were first reared in a nursery and, as each was planted in its plot, care was taken that it was the result of the growth of only one bud. His results are given in the following table :—

Spacing	Number planted in March	Shoots in June	Shoots in October (harvest)	Average weight of each cane	Tonnage
6″	17 600	72,325	39,050	2·17 lb.	42·55
12″	8,800	51,188	32,964	2·49 lb.	41·60
18″	5,860	37,230	29,070	2·60 lb.	37·24

These figures show a greater number of shoots arising in the more closely planted rows, but a gradual diminution of the differences in these numbers as growth proceeded. Inversely, there was an increasing weight of individual canes with greater spacing, but the tonnage was greater in the closely planted plots. Stubbs concluded that tillering depends on room available, and that there is practically no limit to it, provided the space given is sufficiently ample. In 1894-95 he carried out the same experiment with much greater care, studying each plant throughout its growth. Five plants of each of the two varieties, the *Striped* and the *Purple*, were used in each experiment, so that, altogether, there were thirty plants. A book was kept of births and deaths by the chemist in charge, who also labelled each shoot as it appeared. At harvest each clump

was dug up and the labels examined, the parent stalks were marked and their relation to their branches; each cane was separately weighed and analysed. It is impossible to conceive of a more strictly scientific method, and the results are well worth study, especially as the conclusions arrived at are at variance in some respects with those of others to be referred to below. More shoots started with the wider spacing, but the ultimate number at harvest was practically the same. In the chemical analysis of the canes, the main stem had the richer juice and the author claims a gradual decrease in weight and sucrose in successively developed branches. He admits, however, that three canes behaved in a contrary manner, and we shall refer to these below. It is especially with regard to the decreasing richness of juice that other workers disagree with Stubbs and, from the following considerations, it seems to us that the author was scarcely justified in drawing the conclusions that he did. We have not been able to study his original paper, but there are sufficient details given in his book on the sugarcane for our purpose. At the same time attention may be drawn to the extraordinary inaccuracies in the general averages of all the canes, especially in the first table on page 132. There were 139 canes instead of 132 as quoted, and the general averages of Brix and sucrose are obviously wrong, suggesting a whole series of printer's errors more than anything else.

From a careful analysis of the tables, we gather that the crops grown in the two years differed widely. In 1894, 20 parent plants produced 139 canes at harvest, whereas, in 1895, there were only 131 from 29 plants. The sucrose was higher in 1894, and the glucose was much lower. From this it appears that the twenty 1894 plants had more space for development and that they were better matured than the 29 in 1895. A reference to the temperature and rainfall during these two years, fortunately given in chapter V of the book, indicates that this difference was due to the character of the growing seasons. That of 1894 was favourable to the production of good, well matured crops, while that of 1895 was altogether unfavourable, especially because of the excessive rains of May 22–24, when over six inches fell, which checked growth and rendered the important late cultivation of the ground impossible, this being followed by a drought which was equally disastrous. In 1894, with the better growing weather, only one cane was reaped which commenced its growth after July 2; in the 1895 crop 7 out of the 11 classes of canes commenced their growth after July 6, and some arose as late as September. When we remember the author's dictum that "in normal weather, only shoots developed up to July may produce a good stand," we can without difficulty conclude that the 1895 crop, being immature, was not a suitable one on which to found generalizations regarding the relative sucrose contents

of the canes of different ages. The sucrose does, it is true, show a regular decline in the later formed shoots, but this is exactly what would be expected from their increasing immaturity. When, on the other hand, we analyse the figures given for the healthy, well matured 1894 crop, it is not easy to follow the author's conclusions. The average weight of the twenty parents was 2·01 lb. while that of the 119 branches was 2·03 lb. Among the latter, 89 shoots, developed during May and June, weighed on the average 1·97 lb., while the thirty later ones, developed in June and July, averaged 2·22 lb. These figures, indeed, rather point to an increase in weight in the later formed canes. As to sucrose, the 20 parents averaged 13·42 per cent., the 89 of May and June 12·27 per cent., and the 30 of June and July 12·47 per cent. Here there is a marked difference between parent and branches, but no fall in the sugar content of the branches during the season, as claimed by the author. There are two canes, however, at the end of the series, which stand out as heavy, and three with high sucrose content; Stubbs draws attention to these, as exceptions, without being able to explain their meaning. It is possible, with our experience in stool dissections, to throw some light, at any rate, on the two heavy ones.

From the details given by the author on the branching of one plant, we can, without difficulty, reconstruct the scheme of its branching. There were five mature canes and 12 shoots of 5-6 feet in length, whose distribution is given in detail, and the reconstruction is given in Figure 1. This distribution is in general agreement with what we should expect in the branching of a thick cane in the time. Starting with this as a basis, we are also able to build up average schemes for the matured canes of the 1894 and 1895 crops, since the relative numbers of parents and branches are given in the tables. These are given in Figures 2 and 3 for 1894 and in Figures 4 and 5 for 1895.

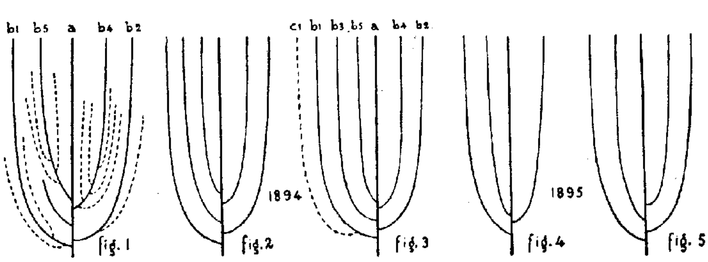


fig. 1 fig. 2 fig. 3 fig. 4 fig. 5

The two exceptional canes in 1894 crop were produced at the end of the branching season (June-July) and were considerably heavier than those

immediately preceding them. The change is rather a sudden one. We shall see, in our dissections, that, in any system of branching, while the *as* or main shoots do not differ very greatly from the *bs* or branches of the first order, there is usually a more marked difference between these two and the *cs*, the latter being generally considerably thicker. It appears to us that, with the favourable season of 1894, it is probable that in some of the 20 plants a branch of the second order may have matured ; while it is highly improbable that any of the 1895 shoots of the same order would be sufficiently advanced to be cut as canes at crop time. In this case we should have, among the 1894 plants, at least two which had a *c* branch matured, as is suggested in Fig. 3 of the diagram, and this would explain the presence of these abnormally heavy canes at the end of the season (*cf.* Pl. XXXII, where diagrams of thick cane branching are shown, and Table on p. 147, where the formulæ of *Louisiana Striped* and *Louisiana Purple*, grown in the Cane-breeding Station, are given).

We think that Stubbs is justified, from his figures, in assuming that, in the Louisiana climate, the mother shoots are at harvest richer than the branches, but we do not think that his facts are sufficiently convincing to assume the regular decrease in sucrose among the younger shoots, excepting where they are also increasingly immature, as in the 1895 crop. We also do not agree with him in his contention that his figures give ground for the assumption that there is a gradual decrease in the weight of branches in the order of development, as it runs counter to all our experience in the dissections which we have carried out, and is not borne out by the figures in his tables. Stubbs's paper is of special interest to us, in that it is the only one we have met with in which any care has been taken to separate the branches of different orders.

The next pieces of work on the effect of spacing on the number of canes produced are in 1910, when independent experiments were conducted by Kilian and Muller von Czernicki in Java. Kilian's experiments[1] were made, with *J. 247*, a late but good tillering variety, on dry loam, "strugge[2]" loam and heavy black clay. It is unfortunate that the control plot of the latter was destroyed by fire ; this class of soil, namely heavy clay, is apparently less suited to *J. 247*, and the results recorded of the single experiment show that some unmentioned factor has intervened. This plot we have accordingly left out in the discussion, and confined our attention to the four others, on loam of varying fertility. Kilian planted his sets in rows $3\frac{1}{2}'$, $4'$ and $5'$ apart, and a summary of his results is given in the appended table, averaging the duplicate plots.

[1] Geerligs, H. C. Prinsen. *The World's Cane Sugar Industry, Past and Pres.*, p. 193, 1912.

[2] We have been unable to translate this word, but imagine that this loam is less fertile.

Spacing of rows		Number of canes reaped per bouw	Weight of canes per bouw in pikuls	Weight of sugar obtained per bouw in pikuls	Sucrose per cent. in the juice
Dry loam ...	3½′	65,089	2,070	197	13·76
	4′	62,771	2,056	201	14·06
	5′	59,163	1,978	199	14·33
"Strugge" loam ...	3½′	55,135	2,092	210	14·40
	4′	54,175	2,023	206	14·58
	5′	50,388	1,946	201	14·81
Heavy black clay (no control)	3½′	40,907	1,633	162	14·23
	4′	48,277	1,745	181	14·60
	5′	40,038	1,536	158	14·75

From this table it is seen that the number of canes harvested decreases regularly with the increased width of the rows ; the total weight of cane varies in the same sense within narrower limits, suggesting that, with wider spacing, the canes are on the average heavier. The quantity of sugar obtained varies irregularly, the advantage in one case being on the side of closer planting ; the sucrose in the juice, however, is interesting, in that there is a uniform rise as the rows are wider apart, and in this respect the aberrant third experiment falls into line, suggesting again that the thicker canes have richer juice. No reference seems to be made by Kilian to this rise in sucrose with wider spacing, but it agrees with the generalization of Kobus and van der Stok that, in the same plot, the thicker canes have richer juice.[1] Kilian is perfectly justified in drawing the conclusion that the results do not point to any advantage in altering the four-foot rows which appear to be most usual in Java.

Muller von Czernicki's[2] experiments were on a much larger scale, and extended over several years. His work is the most important contribution which we have met with on the effect of spacing on tillering, and the number of canes reaped, and deserves careful study. He had noted great variation in the spacing on different estates, without being able to find any reasoned justification for the local practices. For himself, on his Poerwodadi estates, it was a matter of considerable importance how many sets were used per acre, as much of the seed had to be imported and was expensive. He accordingly laid down a series of experiments to determine if equally good results could be obtained with a sparser sowing. He also wished to determine the relative tillering power of the different varieties and the time at which the maximum number of

[1] J. E. van der Stok, in Früwirth's *Die Züchtung der Landwirth-schaftlichen Kultur-flanzen, Zuckerrohr.*

[2] Muller von Czernicki, C. F. Proefnemingen omtrent Plantwijdte. *Archief* v. d. *Suikerind. in Ned. Ind.*, Vol. XVIII, 1910, p. 314.

shoots was reached. At first he dealt with very large areas, planting them with rows 4 and 5 feet apart. There appeared to be no increase in the number of canes with the wider spacing, rather the reverse, and he decided to concentrate on varying the distance of the plants in the rows. But, in this case also, the results were inconclusive, and this he put down to the varying soil conditions and the impossibility of planting control plots in such large experiments. He therefore instituted a number of experiments on plots one-tenth of a bouw in area (practically 17 tenths of an acre or, as it is termed in Madras, 17 cents). The rows were, as usual, 4 feet apart and about 30 feet long. In these he planted *Black Cheribon, J. 247* and *J. 100,* varieties which were of importance in his area. The sets were planted 10, 12, 14, 16, 18, and 20 to the row. Countings were made of the shoots above ground at 60, 90, 120 and 150 days from sowing, which, presumably, roughly coincided with the different earthings up; and, 14 days after the last counting of shoots, he counted the canes formed, with a convention which seems to hold in Java of taking two or even three thin canes as the equivalent of one thick one. Muller von Czernicki complains repeatedly of the depredations of thieves and other injuries in his small plots; the presence of *sereh* is also commented on in the plots planted with locally raised seed, but these injuries are of less moment in the early countings, in which we are most interested here, than in the final crop. Numerous tables and graphs illustrate his paper and of these one table and two graphs are reproduced, as the paper is in Dutch and not easily available. In the table one notes with surprise the very early general development of branches from the sets, a steady decline usually following, after the first couple of months. Muller von Czernicki concludes as follows with regard to the three varieties tested :—

The number of shoots counted at different periods, with sets planted at different distances apart—Muller von Czernicki.

1908 *crop.*

Number of sets planted per row	Number of plots averaged	NUMBER OF SHOOTS COUNTED AT					Crop in pikuls per bouw (1¾ acres)	Sucrose % in the juice
		1st earthing up	2nd earthing up	3rd earthing up	Last earthing up	After the last earthing up		
		Generatie Cheribon						
10		124	122	103	77	61	1,398	15·6
12		138	131	108	77	62	1,416	
14	10	155	147	118	81	66	1,416	
16		178	162	125	85	67	1.404	
18		167	160	124	85	68	1,386	
20		180	170	130	88	72	1,518	15·8

The number of shoots counted at different periods, with sets planted at different distances apart—Muller von Czernicki.

1908 *crop*—concld.

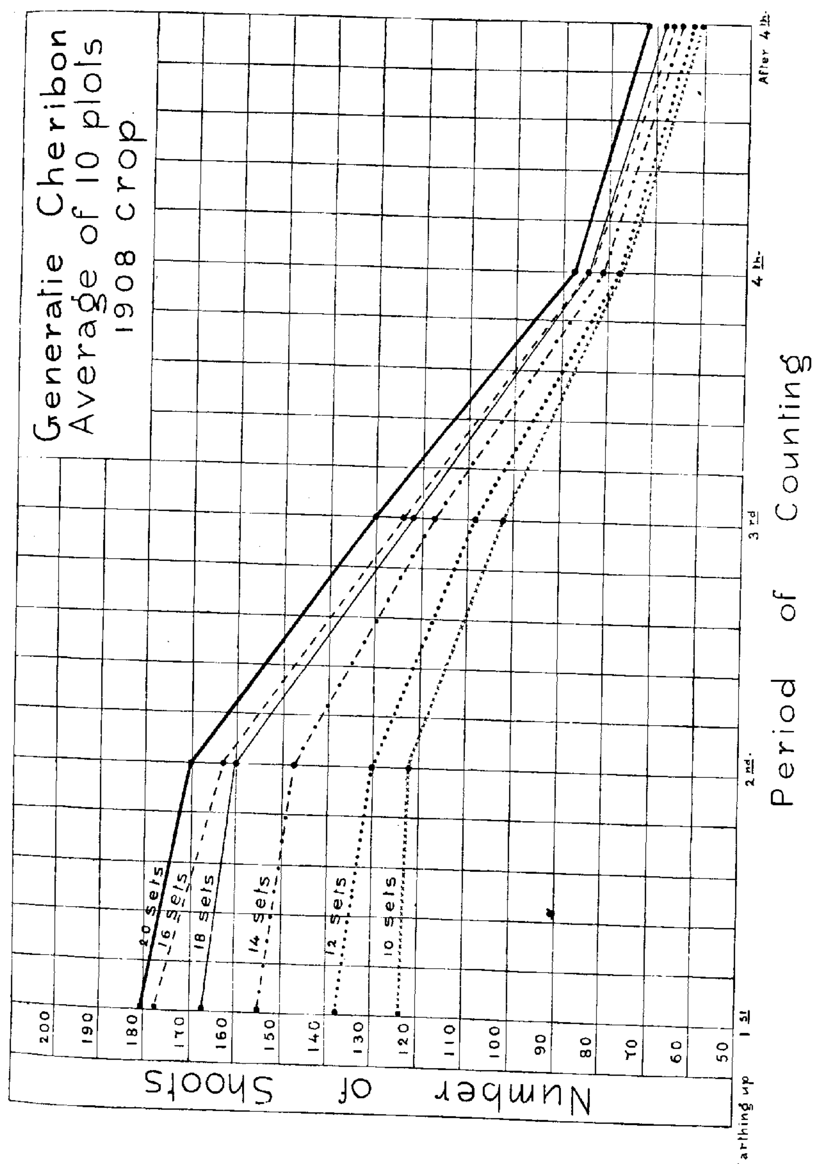
Number of sets planted per row	Number of plots averaged	Number of shoots counted at: 1st earthing up	2nd earthing up	3rd earthing up	Last earthing up	After the last earthing up	Crop in pikuls per bouw (1¾ acres)	Sucrose % in the juice
		Plantriet No. 247						
10	8	120	150	159	114	95	1,728	12·7
12		143	170	166	114	92	1,554	
14		153	175	167	115	92	1,452	
16		165	187	173	117	96	1,530	
18		180	196	180	119	97	1,506	
20		190	212	192	122	100	1,536	13·5
		Generatie No. 247						
10	28	161	168	148	122	101	1,536	13·5
12		191	178	155	122	98	1,422	
14		203	188	154	120	95	1,446	
16		224	192	160	122	90	1,416	
18		232	202	160	122	95	1,446	
20		240	206	160	124	96	1,410	13·5
		Generatie No. 100						
10	3	98	128	124	100	82	1,140	16·7
12		124	140	124	104	83	1,200	
14		127	148	123	104	83	1,220	
16		142	150	128	104	83	1,220	
18		157	146	126	106	86	1,320	
20		168	156	124	106	86	1,320	15·6

Cheribon has the greatest number of shoots at 60 days, that is at the first counting; in the rows with ten sets the maximum is a little later, but at 150 days from sowing all the plots are approximately equal.

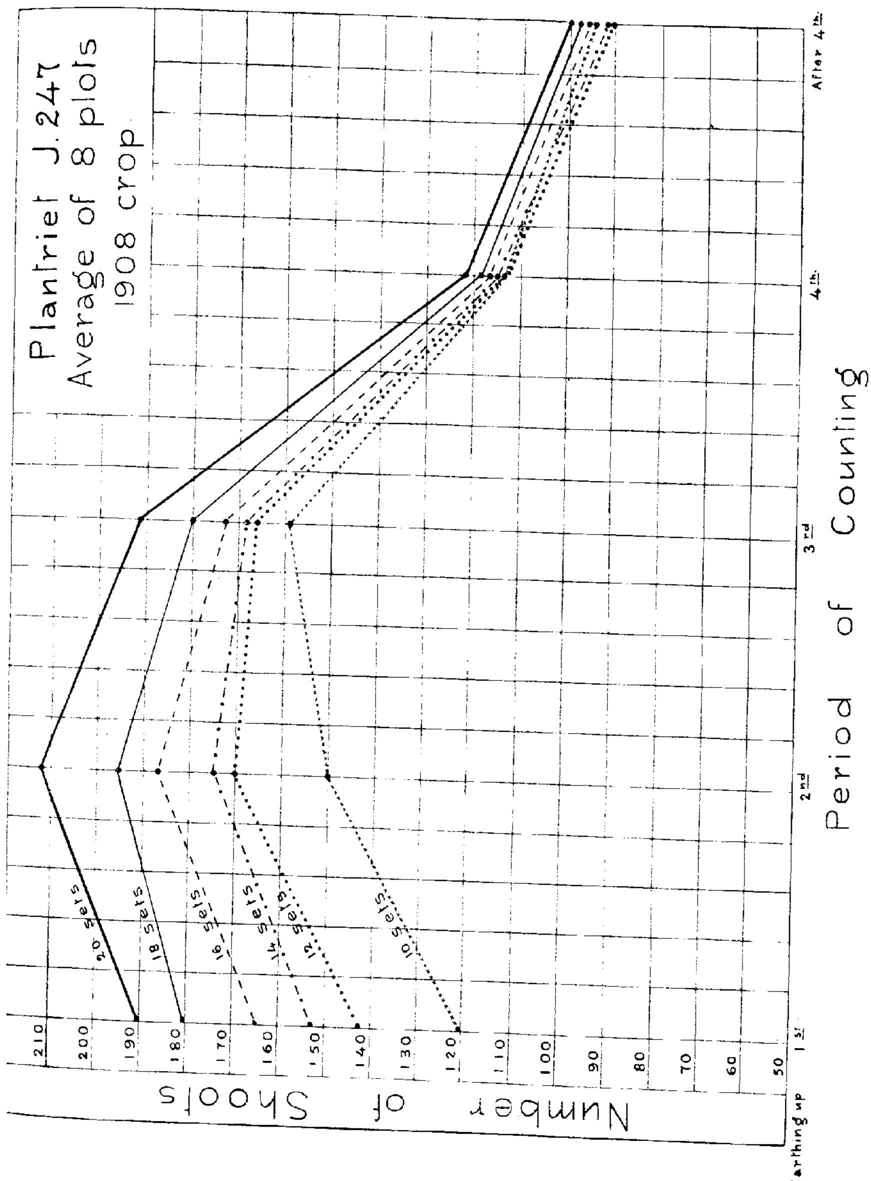
J. 247 tillers more slowly. When planted from sets, the maximum occurs at 90 days, and, in the 10 sets plot, at 120; when planted from tops, because presumably of the greater number of buds, the course of events is practically as in *Cheribon.*

J. 100 (of which only three plots were planted) reached its maximum number of shoots early, the plots with 18–20 sets at 60 days and the rest at 90 days, and after that period there was little difference in the plots.

PLATE XIV.



Shoot-counting table, copied from Muller von Czernicki.



Shoot-counting table, copied from Muller von Czernicki.

An inspection of the table and graphs will convince the reader of the greater tillering power of the widely spaced plants, where of course there were considerably fewer plants to the row, and the subsequent great mortality of shoots which soon reduced the numbers, till they were more or less uniform in all the rows—all the available light being used up.

The author draws the following conclusions regarding the possibility of reducing the number of sets planted per acre. This is of special importance with the costly imported material, and he points out that, with *Cheribon* and *J. 100*, it can be substantially diminished with safety. This also applied more or less to locally grown seed, but the danger of *sereh* is greater and the cost of the seed is much less, so that no change is suggested.

The experiments were repeated in 1909, with 8–20 sets per row, as it seemed to Muller von Czernicki that the lower limits of sowing had not been reached. The results confirmed those of the previous year. In *J. 100*, owing to a mistake, there was only one plot, but in the row with 8 sets a full stand was easily reached.

Muller von Czernicki makes certain observations as to the sucrose content of the mother cane and its branches. He states that some people seem to believe that the mother canes are richer than those developed later, but he cannot find any grounds for this belief. "After many years of observation," he has come to the conclusion that, provided that canes are ripe, there is little or no difference in this respect. He points out that the definition of mother shoot is a very loose one, and quotes Hovenkamp as saying that "mother canes need not be primary stems, but are the thicker and richer canes." We see elsewhere that the assumption is unwarranted, in that the canes of the third order of branching are almost always thicker than the mother canes. And we fail to see in what respect Muller von Czernicki's own deductions are more accurate, in that there are no references to stool dissections, and, without these, it is practically impossible to decide which the mother canes are. He, however, approaches the matter from another point of view. With closely planted sets, there will, he argues, naturally be more mother canes than in widely spaced rows, and this must make its influence felt, if there is richer juice in them, than in the branches; but he has not been able to detect any such difference. Muller von Czernicki's deduction would appear at first sight to be perfectly sound, but he does not go far enough. There will certainly be fewer *a*s in wider pacing, but we do not know whether the relative increase in the numbers of branches of the lower orders is in the *b*s, *c*s, or possibly *d*s. Again, in closer planting, there will be a greater proportion of *a*s in the canes

reaped, but here also we are in the dark as to whether this is accompanied by a diminution of the relative numbers of *c*s and *d*s, which might give the *b*s a predominance over them. This side of the question is of some importance, for we shall see later that, while the *a*s and *b*s are often very similar, the *c*s and *d*s differ radically from them, and the question is thus not only influenced by the relative number of *a*s in the plots, but also whether the *a*s and *b*s on the one hand or the *c*s and *d*s on the other are in relative excess. Until we have more definite information on these points, we should prefer to rely on the actual analyses of early and late canes as given by Stubbs and carried out for some years on the Cane-breeding Station at Coimbatore; but these latter will be referred to later.

Muller von Czernicki states that he has often noted the differences in thickness of canes sparsely and closely planted, especially in the 1909 experiments, and he decided to test this more carefully. He therefore measured 50 canes from each plot in the following manner, making altogether 1,000 measurements. He used a pair of calipers which he moved round the stem until it encountered the greatest resistance, and took the measurements at about one metre from the ground at the middle of an internode. His results are given in a series of tables, in which the canes are arranged according to their thickness in each plot, with differences in millimetres. From these measurements in thickness he deduced the weight of the canes. By using a formula he calculated the difference in average weight of canes in the rows with 8 and 18 sets, the extremes of the series. This difference varied from 10·5 per cent. in imported *Cheribon* sets, to 17·6 per cent. in local *J. 247*. The average of these differences in the four kinds of seed used was 14 per cent., which means that 86 canes in the thinly sown rows would equal in weight 100 in the closer planted rows. In these deductions he assumes that the plants in the different rows were of equal height, but he himself observes that this was by no means the case; he therefore concludes that for accurate determinations of the weights of individual canes direct weighings will alone suffice.

Strüben, in his paper on Tillering (1911), already mentioned, collates numerous countings of canes made by different workers, under the most varying conditions of climate, soil and treatment, and concludes that, within narrow limits, each variety shows the same cane-producing capacity, limits narrow enough not to be of appreciable influence from the crop point of view. He further gives the results of a series of experiments conducted by himself on the lines laid down by Muller von Czernicki. He experimented with *J. 247* and placed 6, 8, 10, 12, 14, 16 and 20 sets in separate rows of the same length,

counting the canes at harvest in each case. The following table summarizes his results:—

Canes reaped at harvest.

Sets per row	*J. 100*: heavy clay		*Cheribon*: fertile land		*Cheribon*: infertile land	
6	74	85	63	68	65	70
8	76	89	69	70	75	80
10	82	89	70	72	82	84
12	85	92	69	76	85	86
14	91	86	72	76	86	85
16	95	86	71	76	86	84
20	94		72	74		

Looking at the figures as a whole, there is a general rise in the number of canes, at first rapid and then slow, as the number of sets per row increases; but this rise appears to receive a check when 12–14 sets per row are reached, and after this there is usually equality or even a slight decline. In only two cases of the six is there anything like a general rise throughout. But the counting of fully formed canes is not a true measure of tillering power, and Strüben's figures do not help us in this respect to the same extent as do those of Muller von Czernicki.

The question of tillering power of the canes in the field, and the effect of this upon the harvest, is thus seen to be somewhat complicated. The number of canes reaped at harvest is connected with the tillering power, but this connection is obscured by the great mortality of shoots during the growth of the plants and is therefore less close than might be expected. Similarly with the weight of canes at harvest; the weight of individual canes in the clump probably varies according to the date of appearance, and the average weight of canes varies with the closeness of planting and the corresponding number of total canes produced. The total yield of sugar depends upon the weight of the individual canes, their number and the richness of the juice. There is some evidence that the amount of sugar in the juice differs in branches of different orders. Spacing the planting material has its influence on all these factors, and it may be useful to summarize the views of the different writers already quoted, and to add such observations on the subject as have been accumulated from time to time on the Cane-breeding Station. The subject will be treated in the following order:—The effect of spacing on the tillering power, as judged by the number of shoots produced per clump, and by the number of canes produced per clump at harvest: on the thickness and weight of the individual canes and the total weight of canes reaped: on the total yield of sugar in the

crop. A note will then be added on the richness of the juice in branches of different orders in the clump.

(*a*) *Effect of spacing on tillering as judged by the number of shoots produced per clump.* Stubbs, in 1892-93, showed that, by planting the sets at 6″, 12″ and 18″ apart, the number of shoots produced differed a good deal. At three months after planting the 6″ plants had, on the average, 4·1 shoots each, those at 12″ had 5·8 shoots, while those at 18″ had 6·4 shoots per plant. Observations have not as yet been made on this point at the Cane-breeding Station. The following figures have been deduced from those published by Muller von Czernicki and referred to above. We have obtained them by dividing the maximum number of shoots in his countings by the number of sets in the row. The cases selected are the extremes and an intermediate one, namely, where sets were planted 10, 14 and 20 in the row. The following are the maximum numbers of shoots for these spacings : *Cheribon* (tops), 12·4, 11·1 and 9·0 ; *J. 100* (tops), 12·5, 10·6, 8·4 ; *J. 247* (tops), 16·8, 14·5 and 12·0 ; *J. 247* (sets), 15·9, 12·5, and 10·6. The extreme differences in these spacings are roughly as 3 to 2 shoots per plant for the wider plantings.

(*b*) *Effect of spacing on the total number of canes per clump at harvest.* We are able to get more cases in which this has been observed, in that countings of canes at harvest appear to have been made regularly for many years in Java. Stubbs gives the figures for the canes at crop time (seven months from planting), in Louisiana, and from these we find that the number of canes per clump at 6″ is 2·2, at 12″, 3·7 and at 18″, 4·9. Comparing these figures with those in section (*a*) we see that, although a number of shoots had died, the ultimate differences had increased.

Kilian gives the number of canes at harvest per bouw (1·75 acres) when the rows were $3\frac{1}{2}'$, 4′ and 5′ apart, and we can obtain proportional figures for the number of canes per clump by multiplying these two sets of figures together. It is to be noted that the differences in spacing were not nearly so great as in Stubbs' experiments, but the results are still very definite. Taking the table given on p. 82, we get the proportional numbers as 4·6, 5·0 and 5·9 canes per clump in the richer land and 3·9, 4·3 and 5·0 in the poorer.

Muller von Czernicki does not give the numbers of canes at harvest, but counts them at 5-6 months, using the Java convention of taking two or three thin canes to one thick. Selecting the rows as before with 10, 14 and 20 sets, we get the following figures :—

Cheribon (tops), 6·1, 4·7 and 3·6 ; *J. 100* (tops), 8·2, 5·9 and 4·3 ; *J. 247* (tops), 10·1, 6·8 and 4·8 ; *J. 247* (sets), 9·5, 6·6 and 5·0. Here again there is an

increase in the differences in the numbers of shoots produced per plant as the period of harvest approaches, which is not to be wondered at, as the effect of the spacing should be cumulative throughout the growth of the plant.

The same author conducted spacing experiments on a very large scale, the plots extending over 100 bouws (175 acres) with sets planted roughly as 2 to 3 for the same space. This again is a smaller difference in space allowance than Stubbs's, but the results are obvious enough. The numbers of canes per bouw are practically equal, showing that the effect of the spacing was that each clump, on the average, produced half as many canes again in the wider planting.

Wider spacing thus has a marked influence on the maximum number of shoots developed per plant; this effect is cumulative, during the period of growth, and is therefore intensified at the time of harvest.

(c) *Effect of spacing on the thickness or weight of the individual cane.* Stubbs gives the average weight of cane when the sets were planted 18″, 12″ and 6″ apart, in lb. as 2·60, 2·49 and 2·17. Kilian's results are less conclusive, but the distances apart in the 3½′, 4′ and 5′ rows were very much less. The relative weights in the two tables were as 3·2 to 3·3 to 3·35 and 3·8 to 3·75 to 3·85. There is thus practically no difference in the weights of the canes. Muller von Czernicki dealt rather carefully with the thickness of the cane, and he deduced the weights on the assumption that the canes were of equal height (which he states from observation is not perfectly correct). He measured the canes at 5-6 months with calipers, in the rows with 8 and 18 sets in them. The result that he obtained from a large number of plots was that the canes in the 8 sets plots were 14 per cent. heavier than those of the 18 sets plots. Other observers, notably Kobus and Van der Stok, emphasize the fact that wider spacing increases the thickness of the individual canes, and it may be considered therefore as incontestible.

(d) *Effect of spacing on total weight of canes at harvest.* A wider spacing therefore produces more canes per plant, and these are thicker and heavier. But there are fewer of these plants to the acre. Stubbs gives figures for the total weight of canes reaped, with his spacing of 18″, 12″ and 6″ in the row, as 37·24, 41·6 and 42·55 tons per acre, a distinct though small advantage for the closer planting. Kilian's figures agree, taking the smaller differences into account in his spacing experiments. The total weights of canes in the 3½′, 4′ and 5′ rows were, in pikuls per bouw, 2070, 2056 and 1978 respectively.

Muller von Czernicki in his larger plots of 3–5 acres obtained "no advantage in yield by planting widely (5′ instead of the usual 4′), rather the reverse," but the experiments he considered unsatisfactory because of variations in soil and the impossibility of having any controls. In his carefully controlled smaller plots, again selecting the rows with 10, 14 and 20 sets in them, he gives the following weights of canes reaped in pikuls per bouw, *Cheribon* (tops), 1398, 1416, 1518; *J. 100* (tops), 1140, 1220 and 1320; *J. 247* (tops), 1536, 1446 and 1410; *J. 247* (sets), 1728, 1452 and 1536, respectively. These figures are in favour of closer planting in the *Cheribon* and *J. 100* plots but in the *J. 247* they are inconclusive, and in fact have higher yields in both cases with the wider planting (Has this anything to do with the known greater tillering power of this variety ?).

On the whole, there seems to be a general concensus of opinion that wide planting reduces the yield in canes at harvest and the best distance apart will have to be decided for each variety, climate and soil as the result of experiments on the spot. With the generally higher yields of closer planting, it becomes a matter for the balance-sheet, especially where the sets are costly, for the price of the latter may then easily exceed the advantage gained by planting more sets to the acre, as was the case in the Samalkota tract referred to above.

(*e*) *The influence of spacing on total yield of sugar.* The factors of moment in the yield of sugar per acre are very numerous. The variety grown, the climate and soil, the character of cultivation, the efficiency of the manufacturing side, the number of canes per acre and their thickness, and the richness and quantity of juice, are all concerned. It is difficult to quote experiments where the effect of all these factors have been considered, but the various workers have given their opinions and these may be summarized, in that they are in general agreement. Within fairly wide limits, close planting appears to give a greater yield, but this is chiefly where the general level of cultivation is low. The local rate of planting is, in India, frequently excessive. This was clearly shown at Samalkota where the same yield in *jaggery* was uniformly obtained with thick canes by planting half the sets generally used. Similar results were obtained as to the maximum yield of *gur* in the experiments at Partabgarh, where, however, only one local cane was experimented with and that of course was a thin indigenous one. A somewhat similar result appears to have been obtained by Stubbs in Louisiana, for he recommends for the maximum crop the planting of the sets 6″ apart in 5′ to 6′ rows.

As to Java, Kobus lays it down as the result of his observations and experiments that even a difference of 10 per cent. in the number of canes per acre may very well go with the same yield of sugar. From this, we gather that the number of canes, which we have seen to be influenced by spacing, is not too closely connected with the yield of sugar, and therefore that the effect of spacing is of little import within moderate limits. This statement of Kobus is taken up by Strüben, who argues in its favour and states that the Editor of the *Archief*, the principal organ of the Java industry, has long held the same view. Kilian's experiment of planting canes in rows, $3\frac{1}{2}'$, $4'$ and $5'$ apart, gave results from which he gathers that, in *J. 247*, the current distance of $4'$ cannot be altered with advantage. In the two controlled experiments on dry loam, the yields of sugar in pikuls per bouw for these spacings were respectively 197, 201, 199 and 210, 206 and 201; while another uncontrolled experiment on heavy black clay gave 162, 181, 158. Muller von Czernicki found, in crop experiments of 3 to 4 acres each over 175 acres, that a spacing varying as 2 : 3 made practically no difference as to yield of sugar. We may therefore conclude, that, with good cultivation, the yield of sugar, influenced as it is by so many factors, has no intimate relation to the spacing of the plants, and that this may accordingly vary within moderately wide limits without disadvantage. These limits have to be determined in each place and with each variety separately.

(7) Note on the relative richness of the juice in branches of different orders.

Kobus has made an oft-repeated generalization, after years of experiment, that, in a cane field, "thicker clumps have heavier canes and richer juice." Van der Stok also asserts that, in a general crop, the thick canes have more sugar in their juice.[1] Stubbs showed that, in the Louisiana crops, the mother canes had richer juice than the branches from it, but he failed to convince us that the earlier branches also had better juice than the later. In Java, writers generally take exception to this imputed superiority of the mother canes, and Muller von Czernicki asserts his conviction that, provided the crop ripens, as it generally does there, there is no difference in the juice of the different orders of branching. This rather discounts the Louisiana results, for a crop reaped at seven months from planting can hardly be considered by cane growers in the tropics as properly matured. But, on the other hand, we have failed to

[1] J. E. Vander Stok, in Früwirth's *Die züchtung der Landwirth-schaftlichen Kultur-flanzen Zuckerrohr*

discover any indication that the true character of the branches has been determined in Java. After a good many dissections, we conclude that it would be a very difficult thing, without experience thus gained, to detect which are the mother canes of the crop. There seems, in general, to be a tendency to assume that these are thicker than the rest, but our results are exactly the opposite, as will be seen in the sequel (Part III, section 6). We cannot therefore think that the opinions on this point either in Louisiana or in Java are altogether trustworthy.

A certain amount of work has been done at various times in the Laboratory of the Cane-breeding Station, on the richness of the juice in the different canes in the clump during growth and at crop time. In our study of early and late canes, we made use of the members of the Pansahi group, because, before we had made our dissections, it was easy to distinguish between the early and late canes. Some of the results of this study have been given in Memoir II (p. 159), where it is shown that, in several varieties (*Maneria, Kahu, Yuba* and *Pansahi*), it was easy to separate the different classes of branches at crop time, and that, in their analysis, the earlier formed canes were invariably richer in their juice than the later. At the close of the 1917-18 crop, an attempt was made to divide the cut canes into classes, by observing the characters by which the branches of different orders could be separated, starting with thickness of cane and, where necessary, introducing length of basal part, average length of lower joints, curvature, etc. This separation was, as usual, found to be specially easy in the members of the Pansahi group. One hundred canes were thus dealt with in each of the varieties dissected and these were divided into their appropriate classes and separately analysed. The results obtained in the members of the Pansahi group are given in the table, and we see that they agree quite well with those given in the previous Memoir. In *Maneria*, the percentage of sucrose in the different classes from earliest to latest was 14·25, 13·74, 13·63, 13·57, 9·80, and in *Yuba* 15·17, 14·86, 13·14, 12·53 and 12·40.

Relative richness of juice at harvest in different classes of canes in the Pansahi group.

Variety and number of plot on the farm	Class of cane	Number of canes	Character of cane	Average thickness of cane in cm.	Brix	Sucrose	REMARKS
Maneria 2716 ...	1	10	very early	1·60	16·90	14·25	The tops were not withered. There was a continued reduction in sucrose content as we passed from early to late canes.
	2	10	early	1·60	16·40	13·74	
	3	19	,,	1·95	16·40	13·63	
	4	28	,,	2·15	16·48	13·57	
	5	16	late (rather immature)	2·25	13·99	9·80	
	6	17	immature	not	analyse	d	
Yuba 2710 ...	1	6	very early	1·55	17·81	15·17	The tops were slightly drying up, but in spite of this the analyses show the same course as in Maneria.
	2	25	early	1·60	17·77	14·86	
	3	24	,,	1·75	17·17	13·14	
	4	20	late	1·45	16·13	12·53	
	5	12	later	2·30	16·13	12·40	
	6	13	immature	not	analyse	d	
Chynia 2711 ...	1	7	very early	1·70	15·30	12·07	Tops dried. This appears to have affected the richness of juice detrimentally in the very early canes. The remaining analyses are as in Maneria and Yuba.
	2	22	early	1·70	17·11	14·34	
	3	36	,,	1·90	16·94	13·75	
	4	14	later than 3	1·80	15·43	12·00	
	5	15	distinctly late	2·20	15·50	11·71	
	6	6	immature	not	analyse	d	
Kahu 2713 ...	1	26	very early	1·60	15·02	12·03	Tops dried. Analyses as in Chynia.
	2	33	early	1·70	16·12	13·10	
	3	28	,,	1·85	15·67	12·14	
	4	8	late	2·35	15·88	11·93	
	5	5	immature	not	analyse	d	
Pansahi 2718 ...	1	10	very early	1·45	13·56	10·76	Tops dried. Analyses as in the last.
	2	26	early	1·65	15·88	13·12	
	3	30	,,	2·00	16·28	13·23	
	4	20	late	2·50	13·06	9·13	
	5	14	immature	not	analyse	d	
Sada Khajee 2719...	1	9	very early	1·70	15·82	12·88	Tops dried. Analyses as in the last, excepting that the fourth class are a good deal the thinnest—possibly late poorly developed shoots.
	2	25	early	1·80	17·84	15·09	
	3	44	,,	1·95	17·44	14·49	
	4	9	,,	1·45	16·58	13·83	
	5	13	immature				

In the remaining members of the group the first formed canes had less sucrose than those immediately following, but this result is not surprising, in that in these varieties the first formed canes are marked as "dried up." We have, from the first, been accustomed to choose the Pansahi class for demonstration of any character which it was desired to emphasize, as there is something peculiarly regular in the growth of these canes, whether in the symmetry of the branching, the regularity with which the characters of the branches of

different orders are displayed or the variation in the sucrose from early to late formed canes; and we have recently discovered that a study of the joint curves of the Pansahi varieties shows that there is a well marked periodicity in the growth during the season.[1] But it is a question whether this almost mathematical regularity in growth is shared by other classes of indigenous canes or is merely a character of this strongly marked group. And the answer to this question is at present by no means easy to give.

A reference to Memoir II (p. 159) will show that, while it was easy to separate the Pansahi canes into classes, this was found to be next to impossible in the other varieties examined at the same time, *Ekar*, *Baroukha* and *Kaghze*; also that, when the attempt had been made, there was no trace of the regular decrease in sucrose in the branches of succeeding orders. Assuming that it would be much easier, with our increased knowledge of the characters, to separate the *as*, *bs*, *cs*, *ds*, etc., of each clump, all the other varieties which had been dissected were treated in the 1917-18 crop as were those of the Pansahi group. Unfortunately, in my absence, and through a misunderstanding, the work was not done until May, when most of the canes, at any rate the earlier ones, were overripe or withered. The members of the Pansahi class seem to have been little affected by this, but it may be the cause for the other varieties failing to show any regularity in the richness of the canes of different orders of branching. On a study of the results of analysis, the figures are so irregular that no object would be attained by their reproduction here, and they are merely recorded in the office files for future reference. There is no trace of the regular decrease in sucrose content from the early to the late canes in these tables, and the matter must be left undecided, until a more satisfactory series of experiments can be conducted. But, on considering the matter carefully, it occurs to us that it will be a matter of some difficulty to conduct such a series of experiments. As each clump approaches maturity, the average richness of its canes increases. This also occurs in each of its individual canes, but they do not run parallel in their improvement, in that the earlier ones will be ripe before the later ones. It appears, from a great number of analyses which we have made at various times, that, while the plants are young, there is a great difference in the richness of the juice in the canes of different orders of branching, but that this difference gradually diminishes as the usual harvesting time approaches; and, when it has passed, that the juice of the earlier formed canes commences to deteriorate until it is distinctly poorer than that

[1] A paper was presented at the Lahore Science Congress, Jan. 1918, in which this periodicity was dealt with. (The subject is further dealt with in a Memoir now in the press; February 1919.)

of later formed branches, which in their turn approach their optimum. This being the case, there will be a point of time in the life of each clump when the juice in the early and late canes tends to be of about the same richness, a period of equilibrium which may be regarded as the optimum of richness in the juice of the whole clump. It is probable that this point of time will vary in each clump of the same variety, even under the same conditions; it is likely that it will vary more in different varieties of the same group, and still more in the different groups. Besides this, the maximum richness of the juice in the clumps in any variety will naturally depend upon whether it is an early or late maturing kind. Mungo and Sunnabile varieties are later in maturing than Nargori and Saretha, and this opens up the question as to when the optimum as regards sucrose in the juice occurs, as it will of necessity be different in different varieties. Reaping all the canes at one time will therefore not be likely to give the desired information, for, while in some the *a*s are the richest, in others these will be overripe and the *b*s or *c*s will have taken their place. In the Pansahi group of canes there is evidence that, generally, the *a*s are richer than the *b*s, and so on throughout the series of canes in a clump, but we have not at present been able to adduce satisfactory evidence that this is the case at crop time in the other varieties dissected. We may therefore, for the present, regard the matter as left for further observation and experiment, and our increased knowledge of the characters by which early and late canes can be detected in a clump should assist in the carrying out of this study.

PART III. DISSECTION OF STOOLS.

(1) SCOPE OF THE WORK.

The number of cane plants dissected for the purpose of this paper is very large, as can be seen from the annexed table (pp. 99–100). It has been attempted to make them as representative as possible of the varieties collected on the Coimbatore farm. The growth of the indigenous canes there is, in general, fairly good, although some have shown themselves to be much more at home than others in the farm conditions, but the thick canes are often not well grown, and comparatively few of these were therefore chosen for dissection, and these rather for distinguishing them from the Indian canes than for comparison among themselves. As the canes of this class were thriving much better on the garden and wet lands of the Nellikuppam plantations in South Arcot, permission was obtained to send a man there for the completion of the series. I am much indebted to Mr. Neilson for his kind assistance in this matter, and the work seems to have been carefully done by Fieldman Rangaswami Pillai, who was in charge of it. We can thus add, to the series, the dissection of 24 clumps of well grown *Red Mauritius* canes, six each in wet and dry land, and a like number of ratooned clumps. All of the other dissected plants were grown on the Cane-breeding Station.

In ranging over so wide a field of study, as indicated by the list referred to and, so to speak, breaking new ground all the time, it was inevitable that many side issues should present themselves, of sufficient interest for further study. There were few mornings, devoted solidly to dissection, which passed without leaving on the mind some new idea as to the direction of the work. Most of these side issues have been prosecuted for a longer or shorter period, to give place in their turn to others, which obtruded themselves by the occurrence of startling examples of what had been casually noted before. The danger of this varying aspect of the work is obvious, both from the point of view of dissipation of energy and of obtaining a connected account, but the observations have, without doubt, afforded an insight into the growth of the cane which could not have been obtained otherwise.

As instances of these side issues, some of which were early incorporated in the work, while others were abandoned after a shorter or longer period of observation, may be mentioned the following. In not a few cases, hints were obtained as to subdivisions and cleavages in the groups of canes, by transitional forms, and these will be referred to later. In the young plants, the relative rates of cane formation in different varieties and groups, the varying length of the tillering period, the relative abundance of the buds of different orders, the large proportion of great white "clawed" buds in certain varieties which suggested a series of broods or flushes of branches, the relative rapidity of development of the main shoots compared with the side branches, and the form assumed by the young branches, often seen in the form of a fan at first, and quickly rearranging themselves to an orderly bunch.

In the older plants, the frequency of a symmetrical arrangement, in ground plan, of the branches when viewed from below, the arrangement and the orientation of the buds on successive branches, the suppression of buds on the inner side of the branches or where congestion occurred; the differing basal curvature of branches of different orders, the squeezing out of branches once formed, the way in which in some groups the branches rapidly became parallel while in others they curved outwards symmetrically or developed into an irregular mass, the manner in which the bud below a set curved upwards, and so on; the relative development of the middle and end buds of a set and the relative value of the position of a bud, whether underneath the set, at the side or on the top; the varying length of the basal, short-jointed portion of the cane in branches of different orders, the effect on this of curvature, with the general result that the mature form of the cane was not assumed until the curved portion was passed, the varying length of the joints in the first two feet; the different periods at which the final cane crop could be safely forecasted by the presence or absence of great shoots on the plant, the application of this to the order of dissection of the varieties; the changes in thickness and shape of the cane, the occasional presence of transverse or median flattening and the relative tereteness of the branches at two feet from the base in different varieties, the narrowing or thickening upwards after the average thickness had been attained, this varying both in different varieties and in the branches of different orders, the thickness and woodiness of the branches at their origin and the consequent firmness of attachment; the difficulties experienced in dissection and in the formation of diagrams and formulæ, due to the breaking off of branches, the intricacy of their development, the squeezing out of shoots, the numerous deaths, the occasional presence of facultative branches, where a branch of a higher order

assumed the characters of one of a lower order which had died, and particularly the difficulty of obtaining representative clumps and plants in certain varieties ; the relative incidence of different diseases, such as mealy bug in the young shoots, the deformations caused by moth-borer and white-ants and the extraordinary manner in which some varieties appeared to be immune to any infection of red rot ; the effect of all these factors on the varietal characters, and the frequent geographical grouping of subdivisions brought out by them.

It is thus not surprising that, during the course of the work, the general scope of the observations has from time to time undergone some modification, and it was not until the second year that a full scheme was developed for the study of each stool dissected. In some of the tables of measurements, only the dissections during 1917-18 are therefore considered. It was obvious that it was necessary to drop most of the side issues, after recording a note, as soon as a decision had been arrived at, and the following were the main lines followed in the second year, in which by far the larger number of dissections were made:—the evolution of a scheme of branching for each plant, variety or group and the discovery of a suitable formula and set of conventions for expressing this ; the relative thickness of each cane at two feet from its base, the length of the basal thickening, short-jointed portion, and the number and length of the joints in the first two feet after this basal portion had been passed ; the rate of maturing of the young plant as regards cane-formation ; the presence of curvatures at the base, runners, deaths, injuries and abnormalities of all kinds, etc. Details on these points are recorded in every dissection, and the various summaries and conclusions contained in this part of the Memoir have been derived from them.

List of clumps and plants dissected.

Group	Variety	1916-17	Young (usually 3-4 months) Clumps	Young Plants	Old (usually 8 months) Clumps	Old Plants	1917-18	Young (usually 3-5 months) Clumps	Young Plants	Old (usually 8-9 months) Clumps	Old Plants
Saretha	Ganda Cheni	...	1	2	2	4		2	4	2	5
	Chin	...	1	3	1	3	...	2	5	2	5
	Hullu Kabbu	...	1	2	1	2	...	2	6	2	6
	Katha	...	1	3	1	3	...	2	4	2	6
	Khari	...	1	3	1	3	...	4	13	2	5
	Saretha	...	1	3	1	2	...	2	7	4	14
Totals	for group	...	6	16	7	17	...	14	39	14	41
Nargori	Baroukha	...	...	...	...	...	...	2	5	2	4
	Katai	...	...	...		...	...	2	6	2	5
	Kewali	...	1	2	1	1	...	2	5	2	5
	Nargori	.	...	...	1	3	..	2	4	2	4
	Newra	...	..	...	...	...		2	6	2	5
	Sararoo	.	1	3	1	3	...	2	3	2	3
Totals	for group	..	2	5	3	7	.	12	29	12	26
Sunnabile	Bansa	...	1	2	1	1	.	2	6	2	5
	Bansi	...	1	2	1	3	...	...	..	...	...
	Dhaulu	...	...		..	..	...	2	2	2	10
	Dhor	.	1	3	1	4	...	6	13	2	4
	Kaghzo	...	1	3	1	3	...	...	..	...	.
	Mojorah	..	...		...	...	.	2	2	2	6
	Naanal	..	1	3	1	3	.	2	7	2	5
	Sunnabile	.	1	3	1	2	...	2	6	2	6
Totals	for group	...	6	16	6	16	...	16	36	12	36
Mungo	Hemja	...	1	5	1	4	...	2	17	2	11
	Katara	.	...	...	...	...	.	2	3	4	12
	Kharwi	..		...			.	2	5	2	4
	Kuswar	..	1	3	1	3	.	2	6	2	7
	Mungo	...	...	...	1	3	.	2	7	2	8
	Rheora	...	...	...	...	...	...	2	11	2	13
Totals	for group		2	8	3	10	...	12	49	14	55
Pansahi	Chynia	..	...	...	...	...	...	2	6	2	2
	Kahu	...	..	...	...		...	2	5	2	5
	Maneria	...	1	3	1	1	...	2	5	2	6
	Pansahi	...	1	3	1	3	...	2	3	2	6
	Sada Khajee	...	..	...	...	...	..	2	4	2	3
	Yuba	...	...	...	...	...	.	2	5	2	4
Totals	for group	...	2	6	2	4	...	12	28	12	26
Unclassified Indigenous	Dhaulu of Phillaur	..	..	...	...	...	.	2	5	2	9
	Ikri	...	...	...	...	...	...	2	6	2	4
	Kassoer (Java)	..	...	...	...	...	...	2	5	2	3
	Khagri	.	...	...	...	...	...	2	5	2	6
	Khelia		1	3	1	2	.	2	6	2	4
	Teboe Monjet	...	...	...	...	...	...	2	5	2	5
Totals	per set	...	1	3	1	2	.	12	32	12	31

List of clumps and plants dissected—(concld.).

Group	Variety	1916-17	Young Clumps	Young Plants	Old Clumps	Old Plants	1917-18	Young Clumps	Young Plants	Old Clumps	Old Plants
Thick canes and intermediate indigenous	Java	8½-9½ months	...	..		3	7	...	(5 months) 2	3	(11 months) 2	5
	Louisiana Purple ..	...	...	...	...	...	...	...	...	(14 months) 2	3
	,, Striped ...	...	...	...	...	...	...	..	...	,, 4	10
	Magh	...	...	...	...	...	...	(5 months) 2	3	...	...
	Vendamukhi ...	...	...	...	...	...	...	,, 2	4	(9 months) 2	3
	Yerra	...	...	...	...	...	...	,, 2	6	(10½ months) 2	4
	Red Mauritius ...	...	(3½ months) 1	3	(9½ months) 1	2	...	,, 2	6	(10 months) 2	6
	,, ...	Ratoons	...	...	(20·25 months) 2	6	...	...	...	...	...
	,, Nellikuppam	Plant canes	...	...	...	...	Dry land	...	...	(12 months) 6	16
	,,	Plant canes	...	..	...	...	Wet land	...	...	(11⅓ months) 6	15
	,,	Ratoons	...	..	...	...	Dry land	...	...	(24 months) 6	10
	,,	,,	...	...	...	...	Wet land	...	...	,, 6	15
Totals	per group.		1	3	6	15	...	10	22	38	87
Wild Saccharums	Sacch. arundinaceum ..	...	...	...	(10 months) 1	2	...	(5 months) 2	5	(7½ months) 2	3
	Sacch. spont. local ..	...	...	...	(6 months) 2	3	...	(5 months) 2	4	(7½ months) 2	6
	,, Dacca ..	...	...	...	...	...	...	(4 months) 2	4	6-10½ months) 6	13
	,, Java ...	...	...	...	...	...	...	,,	...	(7½ months) 2	7
	Saccharum Munja ...	...	...	...	...	...	...	(5 months) 2	5	(9 months) 2	5
	,, Narenga ...	..	...	..	...	...	...	,, 1	3	(9½ months) 1	1
Totals	per group.				3	5	...	9	21	15	35
Seedlings (planted from sets)	M. 5300 Str. Maur. Rogue	...	...	...	...	...	...	(4 months) 2	6	(8 months) 2	6
	M. 2 Kaludai Boothan Rogue	...	...	...	...	...	...	,, 2	3	...	...
	M. 7319 Ashy Maur. Rogue	...	...	...	...	...	...	,,	...	,, 2	4
	M. 1428 Naanal Rogue	...	...	...	...	...	...	,,	..	,, 2	4
	M. 2867 Vellai × Sacch. spont.	...	...	...	...	...	...	,, 2	4	,, 1	3
	M. 10801 Vellai × Sacch. spont.	...	...	...	...	...	...	,, 2	6	,, 2	5
Totals	per group							8	19	9	22

SUMMARY

Group	Variety	1916-17	Young Clumps	Young Plants	Old Clumps	Old Plants	1917-18	Young Clumps	Young Plants	Old Clumps	Old Plants
Saretha ...	Number of varieties 6	1916-17	6	16	7	17	1917-18	14	39	14	41
Nargori ...	,, ,, 6	...	2	5	3	7	...	12	29	12	26
Sunnabile ..	,, ,, 8	...	6	16	6	16	...	16	36	12	36
Mungo ...	,, ,, 6	...	2	8	3	10	...	12	49	14	55
Pansahi ...	,, ,, 6	...	2	6	2	4	...	12	28	12	26
Unclassified ...	,, ,, 6	...	1	3	1	2	...	12	32	12	31
Thick canes ...	,, ,, 7	...	1	3	6	15	...	10	22	38	87
Wild Saccharums	,, ,, 6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(2) The general course of branching.

The sprouting of the buds of the set and their rapid transformation into cane shoots has been described in Part I of this paper (*cf.* pp. 46–50 and Plates IV–VIII). The bush resulting from the planting of a set is termed a *clump*. As there are several buds in each set (usually three in India), and each may give rise to an entirely independent set of stems, leaves and roots, we shall find it convenient to reserve the term *plant* for all that rises from the growth of a single bud. Similarly, we use the term *shoot* for any single axis which develops successive leaves at its apex and, in course of time, forms a cane. This distinction between clump and plant has been introduced in the preceding list of dissections, for it is obvious that the development of each plant will depend on the amount of space available, and this will be found expressed in the formula and diagram of its branching system, later on. Theoretically, with sufficient time and space, the development in any cane plant is practically unlimited, but we find, in practice, that there *are* certain limits in each variety beyond which the branching rarely goes, and that there are considerable differences in groups and varieties in this respect. The joints in the Mungo group are very short, and, in cutting the sets for planting, no care is taken to cut them so that they have only three buds, but a portion of the plant is cut off about the usual length. In our dissections in this group we have accordingly frequently met with a large number of plants in the clump. On Plate XVI the dissection diagrams of two young *Hemja* clumps are shown, with six and eleven plants respectively. Compare with these diagrams those on Plate XXX, in which an older clump of *Hemja* with four plants, and one of *Kuswar* with only one plant are shown. The numbers of living shoots in these clumps are as follows :— *Hemja* four plants 33, six plants 31, eleven plants 31, *Kuswar* one plant 24. The formulæ for such plants cannot reasonably be compared with those of other varieties where only three buds normally occur. It thus becomes a question whether, in preparing our diagrams and formulæ, the plant or clump should be considered the unit. There are, in every form, weak plants in which only a few canes are developed, and, taking a strongly branching form such as *Yuba*, we have the following formulæ for the four plants dissected: $1a+3b+1c$ and $1a+7b+16c+8d+1e$ from one clump, and $1a+3b+5c+2d$ and $1a+5b+5c+1d$ from the other (Pl. XXIII). Here we see a considerable difference between the development of the plants in the first clump, and there are far greater differences in other cases, where some of the plants consist of only one or two canes. On further considering the great number of individual plants in the clump in the varieties of the Mungo group, it thus becomes doubtful whether

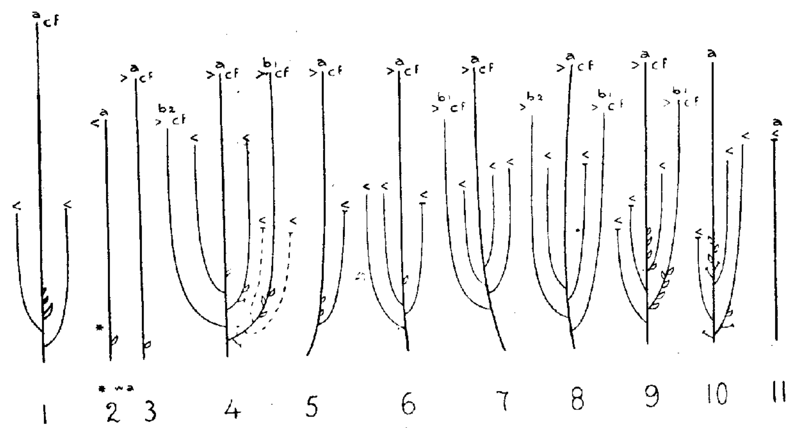
the formulæ obtained for separate plants will be of any morphological value. Undoubtedly, if we planted a series of single budded sets, we should expect better data as to the tillering power of different varieties, but this would greatly limit the field of observation. We have, however, instituted such an experiment during the present season, with the added factor that each plant is allowed as much room as it is likely to be able to occupy. Meantime, it has been found that, with the large number of dissections made, the average formulæ obtained for different varieties are of service, and that the varieties examined differ sufficiently for their mode of branching to be added to the already numerous classification characters which we have observed in our study of indigenous Indian cane varieties. We have, indeed, an additional advantage in this variation in development of the individual plants, namely, that in each case we have a series of plants of different sizes, and are thus in a better position to judge of the ultimate possible development in each case. But, even if the limiting of our formulæ to the plant proved unsatisfactory, we could always at once deduce those for clumps by adding the respective plant formulæ together, whereas we could not make the converse adjustment. And, lastly, it is difficult to see how the *diagram* could be prepared with more than one original main shoot.

At the commencement of our work, it occurred to us that the position of the buds on the set might possibly have an influence on their growth. Thus the end buds of the set might, because of more room, develop into stronger plants, just as they do at the ends of the rows. But, as the result of many observations, we have not been able to trace any difference to this cause, as sometimes the middle bud was the largest and sometimes the end bud. The plants are apparently too close together for this factor to have any influence. Similarly, the relative positions of buds above or below the set had apparently no influence on the ultimate development of the plant, the arrangements whereby the shoots can alter their position being so perfect that they soon were able to place themselves in an equally favourable position (*cf.* Pl. VII, fig. 1, and also Note on p. 51).

We have seen that the bud on a set, on sprouting, develops more or less rapidly into a shoot consisting of joints, leaves, buds and roots. At an early stage of growth, the buds, especially the lower ones, push their way through the enveloping leaf sheaths and also form similar shoots. We indicate the main shoot by the letter *a*, and use *b*s for its branches, or those of the first order; the *b*s in turn give rise to *c*s or branches of the second order, and further branching proceeds on similar lines to the *d*s, *e*s, *f*s, etc., according to the variety

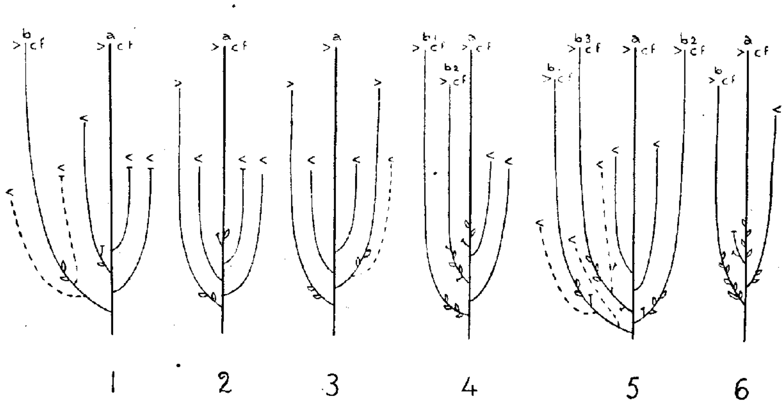
Hemja 1917 (4 months old)

One clump with eleven plants



Hemja 1917 (4 months old)

One clump with six plants

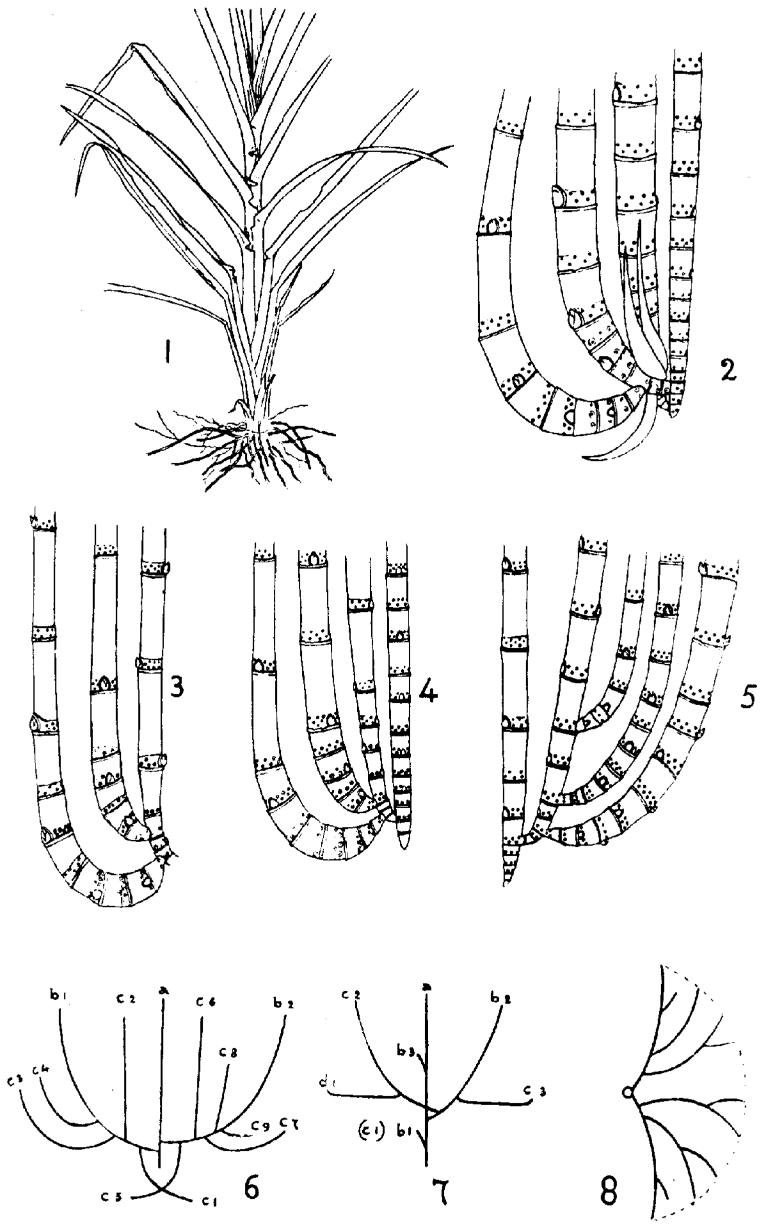


Diagrams of branching system in the plants of two *Hemja* clumps. These figures show what a number of small plants are sometimes found in each clump—which interferes with the comparative plant formula in the Mungo group.

or species and the amount of energy which each individual plant possesses. The *b*s develop more quickly than the *a*s, the *c*s more quickly than the *b*s and so on, until towards the end of the season when the energy available has been largely used up. This increasing rapidity in development is not to be wondered at, when we consider the larger mass of leaves and roots and the greater thickness of stems with their store of nutriment, as time passes and the plant becomes larger. This difference in the rate of growth in branches of successive orders leaves its impress on the final form assumed by the individual joints, especially the lower ones, and this makes it easy to deduce the previous rate of development from an examination of the dissections. At the point of origin, each shoot is extremely thin, and its first effort is to increase its thickness, until that appropriate to the variety has been reached. We have, empirically, but as the result of many observations, assumed that, until the joints reach about one inch in length, the shoot is still in this preparatory thickening stage, and also engaged in the process of branching, for most of the branches are found in this basal, short-jointed portion. And we thus obtain a useful indication of the rate of development of any shoot, by measuring the length of the portion before joints one inch long are reached. The *a*s or main shoots are all distinguished by a long basal portion. But we soon meet with another factor, which influences the length of this part of the stem. This is, that the later formed shoots have to place themselves between or outside the earlier ones before they can start growing freely, and they accordingly take a longer time in passing through their preparatory stage, the basal portion gradually becoming longer again in branches of higher orders.

In considering the way in which later shoots avoid congestion with the earlier ones, we have to study the whole question of the orientation of the buds on successive shoots, and the way in which the latter place themselves in a favourable position for free growth. The main shoot of the sugarcane plant, with its two rows of alternate leaves on opposite sides of the stem, assumes the form of a fan, as is seen in Pl. XVII, fig. 1. Each of these leaves bears a bud in its axil, and the branches, if developed strictly, should all be formed in the same plane. Each of these branches has a series of leaves, of which the first or lowest bud scale lies in the same plane, and, therefore, unless some disturbing influence supervenes the whole plant with all its complex of branches and leaves, if laid out on a table, would be flattened out in one plane. But this strictness of arrangement is usually avoided in nature, for the branches would interfere with one another and the distribution of light would be uneven. Thus, in *Pandanus*, where the leaves are arranged in a series of rows, there is an obvious but gradual torsion

of the stem, so that the vertical ranks of the leaves come to lie in all directions and they do not thus interfere with one another's light and air. There would appear to be a similar torsion, though not always very obvious, which finds expression in the varying *orientation of the buds* in the successive branches of the cane plant (Pl. XVII, figs. 2–5, see also the dissections on Pl. VI). This is specially seen where, as is often the case, the branching is congested low down, all the branches arising from a practically common centre. In other cases it can be noted that the lines of leaves at the base are not strictly opposed, but both tend to approximate to one or other side of the stem, usually the outer side. This dorsi-ventrality of the shoot is especially well seen in *Saccharum arundinaceum*, where the two rows of buds are both on the outer, curving side of the later branches, the inner side being altogether devoid of buds (*cf.* Pl. I, fig. 2 in the left-hand cane and fig. 5 of Pl. XVII). But yet another method is adopted by the plant, in that while the *as*, and often the *bs*, are straight to the base, the later formed shoots are seen to curve in various directions, until a position is reached from which upward growth may proceed, unimpeded by the branches already formed (Pl. XVII, figs. 2–5). The character of this *curvature* varies a good deal in different varieties, and may attain considerable dimensions, and thus be regarded as a varietal character of some importance. Consider, for instance, the way in which the ultimate aim of the plant, to give all its shoots free access to light and air, is accomplished in the different groups. In the Saretha series the clump consists of straight or zigzag branches, sprawling in all directions and often almost lying down ; in Nargori, the canes assume a vertical position at the earliest possible moment and the curves at the base are comparatively short and sharp. In Pansahi, while the central shoots are erect, those outside curve very broadly and regularly, and the clump becomes cup-like in form, and so on (*see* Plates illustrating the groups at the end of this Part). And these various modes of growth, all leave their mark on the basal parts of the canes composing the clump. But this curvature is further assisted by the formation of *runners* which, again, are met with much more frequently in some varieties than in others. The term needs some explanation. We have applied it to those cases where, before the earlier thickening stage of the shoot is completed, one or more long thin joints are intercalated between the first short ones and the later ones, and the thickening process commences a second time. This gives the impression that the shoot, having started its growth along normal lines, finds itself cramped, but has still the power of changing its position, and does so by the formation of a runner. The plasticity of the fully formed branch is not sufficient for this to take place, and therefore runners are usually


1
2
3
4
5
b1
c2
a
c6
b2
c3
c4
c8
c9
c7
c5
c1
6
c2
a
b2
b3
d1
c3
(c1) b1
7
8

confined to the basal, thickening portion of the shoot. It is not by any means necessary that runners should be formed only in a horizontal direction; they may trend downwards or upwards and, indeed, are not infrequently found in a vertical direction (*cf.* Pl. XXVIII). And in this case they remind one of the long preliminary joint formed in a seedling when it is too deeply planted and is not in a position to tiller freely. It is interesting to note that runners do not usually give rise to branches, and that, in the curved portions, it is usual for only the buds on the outer sides to form shoots, those on the inner sides remaining small or dying early.

The curvatures occurring at the base of the shoot are usually symmetrical through a number of joints, and both the nodes and internodes take part in it. In fully formed canes this is not possible in the internode because of the hardness of the rind, but at the node there remains throughout the life of the plant a meristematic zone which makes a bend possible. We thus come across *bends* in the canes long after the curving portion is passed, whereby a shoot is able to assume the erect position and regain it if accidentally thrown down, exactly as in grasses laid by a storm. This bending takes place chiefly in the "growth ring" which is usually greatly increased in width on the underside of the bend. In some varieties this nodal bending is characteristic of all the cane joints, whether it is necessary to alter the position of the cane or not and we accordingly get a *zigzag* cane with bendings in alternate directions. Zigzag joints usually occur in canes with long joints, and hence they are met with in the Saretha and Pansahi groups, but are absent in the short-jointed Sunnabile and Mungo varieties.

This arrangement of the branches of the cane is of great importance for its healthy development. Where the branches are too congested, the buds are suppressed and killed along the contact surfaces or, if they survive, they give rise to small, feeble, whiplike branches which are only very rarely able to force their way upwards and form canes. For the demonstration of this phase of the plant's activity, it is advisable to form a *ground plan* of the shoots, and this is sometimes very instructive. It is frequently possible to separate great sectors of the branching system by merely cutting through successive *b*s at their bases. Such separated portions often assume the form of a crescent and can be easily fitted into the other sectors, and an example of this is given in Plate XVII, fig. 8. Some of the schemes thus produced are highly symmetrical in vertical section (figs. 6 and 7), and show that the arrangement of the branches of the cane, with reference to the light available, is on a par with the fitting in of the leaves of a plant or the tops of the trees in the great primeval

forest. In the latter case, we have frequently been able to detect, on looking upwards, a hexagonal outline for the whole leafy top of an individual tree.

We can now return to the consideration of the way in which the rate and manner of development of the shoots, of different orders of branching, is impressed permanently on the morphological character of the mature canes.

We have measured the basal, short-jointed portion in each cane of each dissection, and find it longer, with a greater number of closely packed joints in the *a*s than in the *b*s and *c*s. In the later formed canes, however, we find the matter complicated by the incidence of curvature, and the length of this basal portion again tends to increase in the branches of higher orders, often indeed ultimately exceeding that in the main shoot. But there is no danger of confusing the different classes of branches on this account. Besides the actual curvature itself, which is absent in the *a*s, there is usually a great thickening in the curved portion in late branches, followed by a rapid thinning when the curved portion has passed; then the change in length is sudden, and quite long joints are immediately reached, as contrasted with the extremely leisurely increase in length in the earlier ones.

In measuring the length and thickness of branches of different orders we have confined our attention to the first two feet of cane. There are several reasons for this. In the first place the dissections would have been practically impossible, if a great mass of leafy canes was attached to the base during its manipulation, so it has been the custom, in the older canes, to cut the clump at three to four feet from the ground before bringing it to the laboratory. Then again, we have learnt, from our series of measurements of the length of joints, that, in the plotted curves, the joints reach their maximum very soon after the cane has emerged from the ground (*cf.* Chart II, p. 175, Mem. III). The longest joints are almost always met with in the first two or three feet, and afterwards there is a regular decrease until the end of the cane. Lastly, we have come to the conclusion that, at two feet from the ground, the thickness of the cane has reached a very fair average, although it is sometimes complicated by a varietal thickening or narrowing after this region has been passed.

In measuring the length of joints in the first two feet, we have omitted the unformed, basal portion, and only started measuring when the first inch-long joint has been encountered. This has also meant the omission of runners and, usually, the curved portion in later formed shoots. In other words, we have taken these measurements only in the fully formed cane. The results have shown a very marked increase in length of joint in the successive branchings, the joints in *b* being longer than those in *a*, and in *c* longer than *b*, and so forth.

In our former studies[1] we used this character to distinguish early and late canes, in that the early canes had short basal joints, while the later ones had longer ones, and we see that this method of distinguishing them was amply justified.

Besides the difference in length, there is also one in the thickness of the branches of different orders. The *b*s are usually thicker than the *a*s, and the *c*s than the *d*s, and so on throughout the series, until the amount of energy at the plant's disposal is exhausted. It may be postulated generally that this increase in length and thickness of joint is, in the main, connected with more rapid and energetic growth, and is the resultant of the action of the mass of roots and leaves present and available for the common use of the plant. Just as the leaves become successively broader and longer in the young plant, so do the stems increase in size. But when we apply this strictly to the successive orders of branches, we meet with another complication. A moment's thought will show that the *b*s in a plant are in a somewhat different position from the *c*s and *d*s. All the *b*s are borne on one shoot, the solitary *a*, but this is not the case in the *c*s and *d*s, which may be borne on any of several branches. We number the *b*s in their order of appearance on the stem, which roughly coincides with the time of their shooting. But in the *c*s we first number those on *b*1, then those on *b*2, and so on (*cf.* Pl. II). While then *b*1, *b*2, *b*3 are in more or less strict order of development, there is no means of telling the order in *c*1, *c*2, *c*3, etc., for it would be quite possible for the first *c* on *b*2 to arise before the second on *b*1. And this difference in the numbering of the *b*s and *c*s places the former in a better position for making observations on any increments in size according to the date of their origin during the plant's growth. For instance, by observing the measurements of successive *b*s, we learn that there is a tendency for an initial increase in size over the *a*s, soon reaching a maximum, and followed by a decline, when the amount of energy in the individual shoot is beginning to wane. There is in fact a general tendency for the *b*s to become thinner as we pass up *a*. A couple of examples, typical of a very large number of plants dissected, may suffice. In M.5300, II_2 of the list, the thickness of the four *b*s are, in mm., 170, 200, 165, 156; in *Kassoer* III the figures for the six *b*s are 274, 165, 167, 140, 121, respectively. This *tailing off* of the late *b*s accounts to a certain extent for the fact which will be noted later, that, in the general summation of the thickness of the branches of different orders, there is less difference between the averages in *a*s and *b*s than between those in the *b*s and *c*s. There are often thin *b*s at the end of the series, whereas

[1] Mem. III, p. 162, &c.

there are fewer *c*s on any one branch, and there is therefore less evidence of this tailing off. The *a*s, if formed at all into strong shoots, are generally well grown, but of only moderate thickness.

The elementary facts here detailed, regarding the general course of growth of the cane plant, may with convenience be studied by a glance at the figures on Plate II of Memoir No. III, of a *Pansahi* plant, and the description of this Plate in the text. A more striking example is given in a couple of photographs of *Saccharum arundinaceum* on Plate I of the present Memoir, in which the variations in length and thickness of joints are very clearly shown. We may be excused for pointing out, in passing, a curious resemblance between the *Pansahi* canes and those of this wild Saccharum. Just as the irregularity and disorder of *Saccharum spontaneum* is seen in the general dissections of the Saretha group, the almost mathematical exactitude of *Saccharum arundinaceum* is reproduced in members of the *Pansahi* group, which, for a moment, suggests the possibility of genetic connection between the latter pair, as well as that now believed to exist between the two former ; but this connection is not confirmed by a general study of the other characters which we have examined.

We have referred above to the early branching period of the growth of the cane plant, and we may now enquire if there is any indication of the same division into the two periods—tillering and elongating—which is seen in grasses (*cf.* pp. 52–55). The matter is complicated by the fact that there is not necessarily a flowering period in the sugarcane, when all the shoots are thrust simultaneously upwards, although the canes cannot attain their proper dimensions without being pushed up into the light and air. Furthermore, as soon as a cane shoot has attained its full thickness, it starts growing onwards in the upright direction exactly like a palm tree, and there is no halt in this upward growth until the inevitable slowing down towards harvest time. Thus, while one shoot is engaged in attaining its full thickness and giving off what branches are likely to have a chance of development, beneath the surface, another is already well formed, well above the ground and rapidly forming solid cane. We cannot therefore easily separate the growth of the plant, as a whole, into a tillering and elongation period, as in grasses. But this is less difficult where some external factor acts as a restrainer on the early growth of the plant. Such, as already noted, are the dry spell in the north of India during the early months of the year after planting, which tends to prolong the tillering period, and the drought in the Godavari District, caused by the annual cleaning out of the canals, often, as already mentioned, accompanied by a determined attack of shoot borer, which kills each shoot as soon as it emerges above ground. But, when we consider

each shoot separately, we see that there are two very distinct periods of growth in it, the first answering closely to the tillering period, when it is increasing in thickness and length of joint and is busy in forming its branches, and the second, when, after attaining its full thickness, it commences to form joints of appreciable length, and rapidly shoots into the air, a stage comparable with the elongating period in grasses. Thus the periods which characterize the shoots of the grass plant at one and the same time are present in the cane plant also, but in each shoot independently of the others. In spite of this fundamental difference, it is possible to separate cane varieties as to their general periods of growth. The term "cane formation" is well known in the fields, and is used to indicate the first appearance of solid canes between the bases of sheathing leaves just above the ground, and this cane formation differs a good deal in different varieties. It is, for instance, much more rapid in the Saretha than in the Sunnabile group (*see* Mem. III, p. 159 and Pl. IV), and still more so than in the later Mungo group. The length of the tillering period thus finds its expression in the rate of maturing of the canes in any clump, and this has been carefully studied in all the varieties; and a special series of dissections has been made for the purpose, at three to four months after planting.

(3) Diagrams and formulæ of the branching system.

In a previous paper a few pages were devoted to the branching system of the Saretha and Sunnabile groups of canes, and to these were added a diagram of the branching of a *Pansahi* plant with several photographs of dissected plants, showing the differences in length and thickness of joints in branches of successive orders (Mem. III, pp. 156–160). The conclusions arrived at were stated to be preliminary, as a much larger series of dissections was projected during the approaching season; but, from the work already done, it was suggested that, by studying the branching typical of any group of cane varieties, some idea might be obtained as to its relations with the more primitive forms on the one hand and the tropical canes on the other, and its place in the ascending series of evolution approximately gauged. Tentative formulæ were suggested to express the general course of branching in particular cases. This work has now considerably progressed, and the larger series of dissections has been completed, presenting us with a mass of interesting material for study.

The grouping of the cane varieties is that adopted in a short paper in the *Agricultural Journal of India* (Vol. XI, Part IV, Oct., 1916). Six varieties of each of the main groups, Saretha, Sunnabile, Pansahi, Nargori and Mungo,

were selected. To these were added six unclassified varieties of indigenous canes, including two recent importations from Java, four of the "Rogues" found in thick cane seedling plots, four wild Saccharum species growing in India, six thick cane varieties and a couple of crosses between these and *Saccharum spontaneum*. In each variety at least four clumps were dissected, two at 3–4 months from planting, in order to study early stages and to determine the rate of maturing, and two 7–10 months old, when the plants were more or less full grown, to obtain general formulæ of the canes and shoots at crop time. These varieties were grown in a special plot, in rows three feet apart and at distances of two feet in the row. The treatment was good and the soil fair. Most of the plants developed well, but in certain cases it was found difficult to obtain good representative specimens, and in such cases recourse was had to the ordinary variety plots, where there was a larger number of plants to choose from. The general aim was to secure moderately well grown plants, and all meagre, stunted clumps were rejected as unlikely to be of comparative value. There was, curiously, special difficulty in obtaining good specimens of both *Saccharum spontaneum* and thick tropical canes. Better specimens of the former were secured from the seedling plots, where *Saccharum spontaneum* was grown as a parent, and of the latter, as already stated, by sending a man down to Nellikuppam in the South Arcot District, where *Red Mauritius* was known to be growing luxuriantly under crop conditions. A certain number of ratoons were included among the thick canes, and, as in these cases the original piece of cane, planted two years before, was still attached, the results have proved of exceptional interest.

On a review of the formulæ obtained, and the general course of branching in the varieties and groups mentioned above, certain doubts have at times crept in as to the correctness of the classification adopted in the *Agricultural Journal* paper. In selecting the varieties for each group, it was attempted to obtain a general representative series, including specimens of all observed deviations from the typical varieties. Certain forms have shown themselves to be aberrant in their branching, and in other cases a series of transitions has been observed between the different types. Thus, in the Mungo group, *Kharwi*, a primitive form, differs a good deal from the rest, especially in the rate of maturing, and appears to approach *Dhaulu* in the Sunnabile group. The inclusion of this cane in the Mungo group will have to be reconsidered, especially as it was placed there as the result of only a cursory examination, owing to its recent arrival on the farm. *Katara*, also only tentatively placed in the Mungo group, and obviously somewhat deviating from the type, has shown in its dissections that it is transitional between *Kharwi* and the others.

The rest are in fairly close agreement with one another. It is interesting to note that, in the Saretha group, the division into the Katha and Mesangan sections receives support, in that *Katha*, *Saretha* and *Chin* develop much earlier than *Ganda Cheni*, *Khari*, and *Hullu Kabbu.* A similar cleavage now shows itself in the Sunnabile group, although this was only suspected when the varieties were examined in Memoir III. *Dhaulu*, *Bansa*, and *Mojorah* develop earlier and branch more copiously than *Dhor*, *Naanal* and *Sunnabile.* The position of *Mojorah*, the thickest in the group and nearest in several respects to thick canes, was unexpected, but it is worth while noting that, both in the Saretha and Sunnabile subdivisions, the cleavage indicated by the dissections is according to geographical regions, the earlier maturing, more richly branching forms being clustered along the Himalayas, while the tardier varieties are found in the Peninsula. In the *Nargori* group, which is generally marked by the homogeneity of its members, *Kewali* and *Ketari* differ somewhat from the rest. But in spite of these irregularities, the general result of the dissecting work has been abundantly to justify the general lines of classification adopted, and, as shown in the study of the Saretha and Sunnabile groups in Memoir III, the branching system yields a character of systematic value. It must be remembered that only a few varieties in each group have been studied, and these remarks on classification must therefore be regarded as suggestive rather than otherwise; but it is worth recording that subdivisions, such as are obvious in the Saretha group, may also be expected to occur in the other main classes, and it is hoped that the apparent uniformity of the various groups may break down on further study, for this is to be expected in any natural system of classification.

The form of the diagram, recording the dissections of plants in full grown clumps, is similar to that given for the *Pansahi* plant figured in Memoir III (p. 157), and the character of the lines used for the branches of different orders is the same as in that figure. Certain conventions have been introduced, which may be summarized as follows :—

(1) Sleeping buds are altogether omitted as having nothing to do with active branching. Only those much swollen or bursting have been included and their relative size is indicated. Large, white, clawed buds are, it is presumed, still under ground, and the dividing character between them and the small shoots is the presence or absence of any green at the tips.

(2) Dead buds are indicated by a short line with a cross line at the end. The same cross line shows dead shoots or canes. Most of the diagrams have no distinction between resting and burst buds, which have died.

(3) The term " shoots " is reserved for such as have green leaves, and these vary from tiny ones just emerged above the ground to those already forming immature canes. They do not reach the top of the diagram, this position being reserved for what are considered fully grown canes; the length of the shoots is indicated by a set of empirical figures, 1′, 2′, 3′, etc., which roughly indicate the relative stage of development without accurate measurements having been taken. When shoots are large and have formed canes below, which, it is assumed, would be sufficiently matured to reap as canes at harvest, they are distinguished by the letters *cf*, *i.e.*, cane-forming, at their ends, and such shoots are included in the formula of canes at harvest.

(4) The term "runners" is used in rather a wide sense, as described on page 104. When the initial thickening stage at the base of the young shoot is interrupted, and a few thin, long joints are intercalated, after which the thickening is resumed, this intercalated portion is called a runner. They are specially found in late formed canes, where the space available is not sufficient for free growth; but it is to be noted that they occur more frequently in some varieties and groups than in others. They are marked in the diagram by an added fine parallel line along the part where they occur. Examples may be seen in Plates XVIII and XXX

(5) Attacks of white-ants and moth-borer, and other injuries, are indicated by an asterisk with descriptive letters added. Shoots thus attacked are usually rejected in forming averages, because of the disturbances induced in the length and thickness of the joints following the injury.

A couple of diagrams are appended in which these conventions are used. We have selected *Katha* I3 and *Sunnabile* I3 of the list, as showing most of them clearly (Plate XVIII).

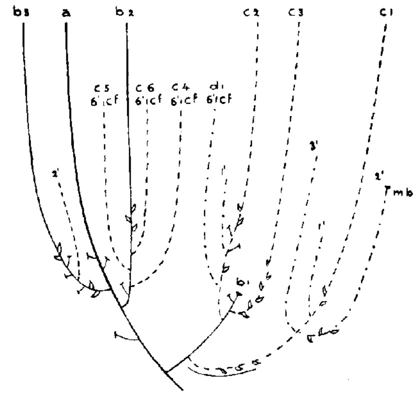
The formulæ of these are as follows :—

Katha I3. Canes, $a+4b+4c+5d$; shoots, $3c+2d$; buds, $3c+5d$; Dead, $1b+7c+4d$; Runner, $1d$.

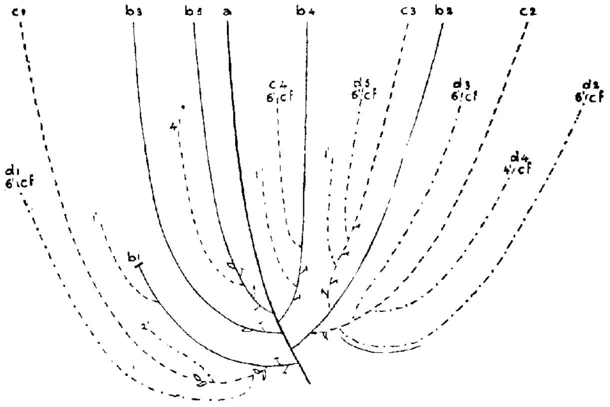
Sunnabile I3. Canes, $a+2b+6c+d$; shoots, $1c+3d$; buds, $7c+14d+3e$; Dead, $4b+5c+2d$; Runner, $1c$.

A word is here necessary as to the time at which the dissections were made. It was unfortunately impossible to dissect the different varieties at the same time. It is rather a tedious process, and the number done was very large. In the 3–4 months' dissections, the time occupied was about six weeks, and it was arranged to do the early maturing kinds first, and leave such late groups as the Mungo until the end. This was found to give satisfaction, although of course the observed differences in the rate of maturing were thus

Sunnabile I 3



Katha I 3



Two diagrams of the branching in dissected plants, to illustrate the conventions used.

made less than the reality (*cf.* p. 127). The 8–10 months' clumps took at least three months to dissect, but the same method was adopted, and it was found that it was perfectly possible, at this stage, to decide what canes would be matured at harvest time. This, however, applied only to the cultivated canes. The wild Saccharums do not exhibit any special ripening, as, for a crop time, and the dissections made from six to nine months show great individual variations in the rate of cane-formation. There was, in these forms generally, an absence of large shoots which were not cane-forming at the base, at whatever time the dissection took place, and in this respect they were at variance with the rest. This fact shows that, in the cultivated canes, the general plan of cane-formation for the season is laid down months before the harvest, and the differences in the periods at which the dissections were made were of little importance with regard to the end in view, which was to obtain a scheme for each plant of the number and character of the canes formed, with a general view of the shoots and buds and deaths occurring. The thick canes were dissected late, on the assumption that cane-formation was very tardy; but this has not turned out to be altogether the case, as will be seen later. The matter is, however, of less importance, in that most of the thick canes were dissected at crop time, and thus all immature canes were at once rejected as not fit for cutting at harvest.

The work was not without its special difficulties. The absence of well grown representative specimens in some varieties in the dissection plots has already been referred to. It is probable that, in these forms, not usually growing well at the Cane-breeding Station, a more elaborate form of branching may be more characteristic, as, for instance, in members of the Katha section of the Saretha group, but this irregularity in the development of varieties would probably occur at any one place where all the forms were being grown together; and in the present case it was merely considered sufficient to note in the record that such and such variety was poorly grown. In some cases the branches were formed very near the base of the stem, and so intricate a mass was revealed that it was almost impossible to get a connected picture of the branching system. This was, for instance, the case with *Kaghze*, which, however, for other reasons, was rejected in the later dissections. In yet other cases, the attachment of the canes at their base, whether to the original set or to the later stems, was extremely thin and brittle. Such were bodily removed, their places of insertion being marked by a series of duplicated pins with numbers attached, and the general plant was then reconstructed after all the sectors had been independently dissected. But a study of this firmness of attachment showed at once that it varied greatly in the different groups,

the *Chin* allies being very lightly fixed together, while in the Pansahi group there were thick, broad attachments which gave the impression of growth in thickness for some time after their formation. While then, it was very difficult to do the Saretha dissections, it was always easy to lay out great sectors of the Pansahi clumps with all the branches attached. The firmness of the attachment is of some importance as a group character and notes have been recorded on it.

Another more puzzling factor was the frequent deaths of both young and old branches. There seemed to be some ground for assuming that, when a stem died, its place would be taken by one of its branches, which would take on its characters in whole or in part and thus become a *facultative branch* of a lower order. In other words, when an a died, its place might be taken by one or more bs, which would assume a characters. This would, of course, interfere fundamentally with the typical diagram, as well as the distinction of the classes a and b in that plant. We have seen that there are a number of characters by which we can distinguish between the branches of successive orders, and we have always kept an eye open for the presence of facultative branches. And there have been, undoubtedly, a number of cases where these occurred; but in the great majority of the specimens examined, the death of an a did not seem to have a very great influence on the measurements of bs and subsequent branches formed. There were, however, all stages between a very slight or doubtful influence and an obvious facultative b, so that, wherever possible, plants with sound as were used for dissection. Some varieties appear to be much more liable to lose their as than others; for instance, in Saretha, it was found impossible to do without a considerable number of missing as in spite of a large number of clumps dissected. It is probable that the time at which death occurs has a considerable influence in the matter. If it occurred when the successors had already formed their basal joints, its influence would be small, as our observations have been confined to the lower parts of the cane. If, on the other hand, the death of a shoot occurred very early, it would be quite possible for a facultative branch to take its place for the purpose of producing the necessary number of shoots in the plant. Although the formation of such a facultative branch is by no means a necessary sequel to the early death of a shoot, it somewhat seriously interferes with the regularity of the diagram. For instance, if a c dies after its basal portion is formed, it gives rise to one or more ds, and thus lengthens the formula. A case of this can be seen in the diagrams illustrating the branching of Thick canes (Pl. XXXII, lower figure). There are two plants in the clump and their formulæ are, for the smaller plant, $a+4b+1c+2d+e$, and, for the larger, $a+4b+6c+d$.

An examination of the figures shows that a c has died early in the smaller plant and that from its stump $2ds$ and $1e$ arise. If this death had not occurred, the formula would have been $a+4b+2c$ or perhaps $a+4b+2c+d$, and the unusual e would certainly not have been developed. And many similar examples could be given, where the death of an a, b or c, causes an abnormal lengthening of formula.

Lastly, the congestion at the base in such forms as *Chin* and *Kaghze* introduces numerous irregularities which interfere with the formulæ and the measurements taken, it apparently being the merest chance whether suppression occurs or meagre shoots survive for a time, or a cane forces its way through and ultimately matures, often showing marks of its struggle for existence. All of these and other factors have their influence on the regularity and symmetry of the branching system, and have made the preparation of characteristic formulæ more difficult.

Appended is a summary list of the formulæ of canes at crop time for each group of varieties dissected. In this list, fractions are treated in the usual way, in that halves and fractions below a half are ignored, while fractions over one-half are counted as equal to one. In some cases there is only one variety in the formula, as in *Saccharum arundinaceum* and the *Red Mauritius* cane, dissected at Nellikuppam. The six unclassified indigenous Indian varieties do not of course form a group, but have been taken together in this list. In *Saccharum spontaneum* there are three varieties, which differ among themselves even more than the ordinary varieties of a group, but they have been taken together for convenience. There are six varieties each in the Saretha, Pansahi, Nargori, Mungo, Sunnabile and Thick cane groups. To these are added four Rogues from thick cane plots and two Crosses between a thick cane and *Saccharum spontaneum*. The group formulæ are prepared in two different ways. At first the formula was obtained for each variety, and these formulæ were averaged for the group to which they belonged. But it was thought possible that a better average would be obtained if all the plants· in each group were added together and averaged, and this was accordingly done The two sets of figures are distinguished by the words " varieties " and "plants" in column No. 2. Besides these formulæ of canes at crop time, a summary has been made of all the stems and branches, with their shoots and buds whether living or dead. These will, it is thought, give a general idea of the branching capacity of the whole plant, but these combined formulæ are less symmetrical and instructive than those of canes at crop time. The latter may be regarded, in some sort, as the total output of the plant, analogous to the

ear heads of a cereal, for the cane plant has long been cultivated for the special development of as many matured canes as possible.

Average plant formulæ of the groups dissected.

Group	Averages of plants or varieties	Number	Canes at crop							Canes, shoots, buds and deaths							
			a	*b*	*c*	*d*	*e*	*f*	Total	*a*	*b*	*c*	*d*	*e*	*f*	*g*	Total
Saccharum arundinaceum	Plants ...	5	1	4	6	6	5	0·4	22	1	4	10	9	9	7	2	42
Saccharum spontaneum	Plants ...	17	1	4	7	5	2	0·4	19	1	5	16	25	11	3	1	62
	Varieties .	3	1	4	6	5	2	·4	18	1	5	15	24	11	3	1	60
Pansahi ...	Plants ...	29	1	3	4	2	..	...	10	1	6	13	14	6	.	...	40
	Varieties ...	6	1	3	4	3	...	...	11	1	6	14	17	7	...	.	45
Mungo ...	Plants ..	59	1	2	2	1	..	...	6	1	7	17	11	3	...	.	39
	Varieties ...	6	1	3	3	2	...	...	9	1	7	18	14	5	..	...	45
Saretha ...	Plants ...	53	1	3	3	1	...	...	8	1	6	14	10	2	...	...	33
	Varieties ...	6	1	3	3	1	..	...	8	1	6	15	10	2	..		34
Nargori ...	Plants ...	33	1	3	3	...	...	..	7	1	5	12	4	...	...	..	22
	Varieties ...	6	1	3	3	...	...	...	7	1	5	12	4	..	...	...	22
Sunnabile ...	Plants ...	46	1	3	2	...	...	...	6	1	7	17	7	...	...	...	32
	Varieties ..	6	1	3	2	...	..	...	6	1	8	16	6	...	...	...	31
Thick canes {Cane-breeding Station}	Plants ...	41	1	2	1	...	...	...	4	1	7	11	7	...	..	...	26
	Varieties ...	6	1	2	1	...	...	...	4	1	8	12	8	...	..	..	29
Red Mauritius {Nellikuppam}	Plants ...	12	1	3	3	1	...	...	8	1	9	19	8	1	...	.	38
Unclassified indigenous varieties	Varieties (6)	plants 33	1	4	2	...	...	..	7	1	9	24	9	...	...	...	43
Rogues in thick cane plots	Varieties (4)	plants 17	1	3	5	4	0·5	...	13	1	8	19	24	9	1	...	62
Crosses, Thick canes by wild Saccharums	Varieties (2)	plants 8	1	3	3	...	...	...	7	1	6	22	15	...	...	...	44

With regard to these two methods of obtaining the formulæ, it may be noted that, for canes formed at harvest, the two methods show little difference in the result. The greatest difference is seen in the Mungo group, where the summation of the 59 separate plants gives a formulæ of $1a+2b+2c+1d$, whereas that taken by averaging the six varietal formula is $1a+3b+3c+2d$,

The two formulæ for Saretha, Nargori, Sunnabile and the Thick cane group are identical, and in the rest only differ in one figure. In the table the groups have been arranged according to the length of the formulæ. The wild Saccharums and the Thick canes are, as might be expected, at the ends of the series, and the indigenous Indian groups occupy an intermediate position. The *Red Mauritius* canes grown at Nellikuppam show an extension of the formula over that of the six varieties grown at the Cane-breeding Station. One idea in having these canes dissected was to see how far the formula of a thick cane might be extended under favourable conditions. Only good clumps were dissected, the distance between the rows was four to five feet in place of three feet at Coimbatore, and there could not well have been greater difference in the character of the soil. That at Nellikuppam is a free sandy loam not unlike the soils met with in the Gangetic alluvium, in place of the rather heavy, slightly saltish land at Coimbatore. Besides this, the *Red Mauritius* variety is noted as a rather free tillering kind. We have accordingly kept this series separate, for, if comparisons are to be instituted between them and the Indian canes, these too should be grown in the places best suited to them. There were many plants in the clumps of most of the varieties dissected which were poorly grown, often only consisting of one or two canes, and there were also, occasionally, abnormally large single plants. By the employment of a sufficiently large number of individual dissections, both of these extremes have been ruled out, and it is assumed that a fair average has been obtained for each variety and group.

The wild Saccharums head the list in the extension of their formulæ, and the large number of *es* in *Saccharum arundinaceum* suggest that a single *f* might with propriety be added to complete the series, which would then be 1 : 4 : 6 : 6 : 5 : 1. The average figures have accordingly been examined to see what decimals were present at the end of each formula. Where such a decimal exceeds one-quarter, it has been inserted, and it is seen that this only occurs in the wild Saccharums and the Rogues from the thick cane plots. We should expect that the full form of the Pansahi formula would be 1 : 3 : 4 : 3 : 1, Nargori 1 : 3 : 3 : 1, and perhaps Sunnabile 1 : 3 : 2 : 1, but the decimals which could be added are insignificant. We may therefore suggest that well grown specimens, or those under suitable conditions of growth, are likely to have such an extension of the formula, as there is a marked tendency in all the formulæ for a fairly symmetrical series of figures.

As regards the acclimatization of the different kinds, *Saccharum arundinaceum* appears to be either very hardy or perfectly at home. The latter is

most probable, as this plant has been grown for many generations in the south of India, and indeed in the immediate neighbourhood of the farm, on richly cultivated land as a fence round *betel* (*Piper Betle*) gardens. The Pansahi group seems to be also very hardy and little incommoded by the occasional saltness of the land on the farm. Saretha varieties of the Katha section do not grow well on the farm, and *Saccharum spontaneum* is not, at first, at home in the cultivated land. The Mungo series is obviously at a disadvantage because of the comparatively large number of plants per clump. The result given in the table must therefore be taken as for one place only, with its many peculiarities, in many cases not the best suited for free growth of the variety. But it is improbable that any one place could be found where all the varieties grown would be equally at home. With this word of warning, we can proceed to analyse the averages in the table. The Thick canes, in the character of their branching, show themselves furthest removed from the wild Saccharums. Then come in order the Sunnabile and Nargori groups which approach the Thick canes, then Saretha, Mungo and Pansahi, which are nearer to the wild kinds. There is no reason to assume, only from the formulæ above given, that Saretha is nearest to *Saccharum spontaneum,* although we have noted many other similarities in Memoir III. The suggestion rather obtrudes itself afresh that the Mungo and Pansahi groups of canes may have arisen independently from some wild parent, and this agrees with the strongly marked characters of these types. The details in each group find no place here, and would fill up a large number of pages. A few notes on them are added at the end of the Memoir.

The above remarks refer to the formulæ obtained from averaging the canes formed at crop time. Shoots and burst buds and dead branches also have their significance in the branching system, and we have included these in a second series of columns. We may now turn to them to see if they show anything of interest. It must be acknowledged, however, that the deaths have not been very wisely marked down in the dissections. For them to be strictly included in the branching system, only dead buds which had already burst should have been counted. But while this was done at first, towards the end of the work all dead buds were counted, on the assumption that they died in the effort of growing out, which was probably often not the case. On considering the enlarged formulæ, we find that the general tendency is the same as that in the canes at crop time. The Sunnabile and Nargori groups are now indistinguishable from the Thick canes, the greater shooting in the latter being possibly due to their encouragement in the process of ratooning or growing for a second year from the same root stock. Some note may be taken of the

different degrees of development of certain classes of buds and shoots in the different classes. In *Saccharum spontaneum* and the Rogues from the thick cane plots, it is the *ds* which form the bulk, these groups being closely followed in this by the luxuriantly growing members of the Pansahi group. But in the latter, the *cs* are nearly as well developed, and this order of shoots is dominant in the other groups, especially in the Nargori and Sunnabile forms. This dominance of certain orders of branches is probably connected with the formulæ already discussed above, the tendency being in each case for the full series of branches not to be symmetrical, but for the maximum to be thrown forward, so that the higher members come beyond the middle of the series.

Turning to the formulæ in the odd lots, the six unclassified indigenous canes, the Rogues and the Crosses between a thick cane and *Saccharum spontaneum* show certain peculiarities. The cane formula for the six unclassified indigenous varieties is very short. This can be easily accounted for by an examination of the varieties selected. They were not intended to be representative in any way, but were such as for one reason or another were interesting. Thus the three *Khelia, Khagri* and *Ikri,* apparently closely related to one another, showed a considerable likeness to the Thick canes, and *Teboe Monjet* has a similar formula. *Dhaulu of Phillaur* approaches Sunnabile in its formula. This was rather unexpected, as this form is considered, from other characters, to be near the Mungo group, but its formula suggests the idea that it may be a connecting link between the Mungo and Sunnabile groups. *Kassoer,* a strong-growing Java form, has the only extended formula, and resembles Saretha in this. The average of the six cannot therefore be taken as representative of indigenous Indian canes generally, and they were not intended to be so.

The Rogues show a very long formula and produce an immense number of shoots of all kinds. This is in accordance with their great vigour and marked primitive characters. The crosses of *Vellai* by *Saccharum spontaneum,* on the other hand, show surprisingly little influence of the male parent in their branching. The formula is extremely short, practically that of Nargori and Sunnabile, which groups are near to the Thick canes. This nearness to the Thick canes is also shown in the richness of the juice in these two seedlings, which is not in any way intermediate between the wild Saccharums and *Vellai.*

(4) AVERAGE LENGTH OF THE BASAL, THICKENING PORTION OF THE CANE, IN BRANCHES OF DIFFERENT ORDERS.

It was noted above that, in judging the average length of the joints in the lowest two feet of cane, the narrow basal region, where the

joints had not as yet reached one inch in length and were still in the process of thickening, was excluded. The selection of this one inch length is purely empirical, but it answers the purpose well enough. The joints in this region are very numerous and, towards the base, present the appearance of a series of superposed discs, with difficulty separated from one another. We may consider this portion of the cane as that engaged in attaining its full thickness and in giving off branches, as contrasted with the following elongating portion, and it presents certain characters which may be now briefly considered. As it is the formative region, in which the whole system of branches must arise, it is not surprising that it is longer in the main stem than in its branches. It has been measured in all the canes in each plant examined, and the table shows the general averages of each group. We see there, that, while in the *as* of all the groups its average length is 3·7″, it is 2·6″ in the *bs*. We should expect a similar difference between the *bs* and the *cs* and so on, but this is not the case. In fact, in most groups, there is a distinct increase in the length of the basal part in succeeding branches after the *bs* are passed. This fact has been already explained by the presence in these later branches of curvatures, whereby they may be placed in a better position for developing freely. And it has been noted that, where there is such a curve, the joints remain short until the cane has straightened out and is in a position to grow upwards in a vertical line. In the Thick canes, in the Mungo group and in *Saccharum spontaneum*, there is a continuous reduction in the length of the basal part throughout the series of branches. This is readily explained in the first and last cases, in that curvature is generally less evident in them, in the Thick canes because of their comparative fewness, and in the wild Saccharum because of the thinness of its branches, their general irregularity and the constant presence of runners. In *Saccharum spontaneum* the shoots are placed in a position for free development rather by runners than by curves, and the result is that the whole complex of branches in the clump is loosely knit together instead of being closely compacted as in the cultivated canes. In Mungo the case is different. There are a great number of canes in the clump, but these arise from a large number of separate buds, as many as 11 having been noted in one case. It is possible that this even distribution of the individual plants along the length of the set may serve the purpose of placing them, and thus do away with the necessity of much curving. But curving is present, as also are runners, and the regular decrease in the lengths of the basal portions of branches of successive orders comes somewhat as a surprise. We have to wait until the *ds*, before we get the expected increase in length. With these two tendencies in opposite directions, we get, in the averages of all the groups, a uniformity in the lengths in

bs, *cs*, and *ds*, which is rarely met with in the individual plants. As in other cases, we have to turn to *Saccharum arundinaceum* for the complete regularity of the series. Here the lengths in *a* average 2·9″, and there is a sharp drop to the *bs* with 2·1″, followed by increases to 2·4″, 2·9″, 3·2″, in the succeeding branches of higher orders. A glance at the uprooted clump in this species will show the increasing curvature which is a dominant factor in this character (*cf.* Pl. I).

Average length of basal part, with joints under 1″ in length, in inches.

Group	No. of varieties	*a*	*b*	*c*	*d*	*e*	*f*	Remarks
Saretha	6	3·1	2·0	2·1	2·5	2·3	(1·5)	The figures in brackets are such as occur only in one case and may be disregarded as not representing an average for the group.
Sunnabile	6	2·7	2·1	3·2	2·6	...	...	
Pansahi	6	3·4	1·7	2·0	2·4	(2·0)	...	
Nargori	6	5·6	2·5	2·8	(2·1)	...	...	
Mungo	6	4·6	3·6	2·7	3·7	(2·3)	...	
Various indigenous ...	6	5·0	3·3	3·1	3·4			
Rogues	4	3·9	2·6	2·9	2·5	(2·1)	(1·5)	
Crosses	2	2·8	2·4	2·8	(3·8)	..	...	
Thick canes ...	6	4·3	3·7	3·3	(3·4)	...	...	
Red Mauritius at Nellikuppam	1	3·5	2·8	2·5	2·3	1·9	—	
Saccharum spontaneum ...	3	2·6	2·0	1·6	1·6	1·9	(0·6)	
Saccharum arundinaceum ...	1	2·9	2·1	2·4	2·9	3·2	...	
Average of all the groups ...	...	3·7	2·6	2·6	2·7	2·4	...	

(5) Average length of joints in branches of different orders.

The main shoot arising from a bud on a set is different from its branches in several respects. It has been shown that it takes longer to develop, in that the plant is small and weak at first; it has a longer basal, branching portion; it is also markedly shorter jointed than its successors. This will be seen from the Table, where the lengths of joints in the *as*, *bs*, *cs* and branches of higher orders have been averaged for the different groups. It may be noted that the numbers of branches dealt with are not the same as in the formulæ of matured canes, for even immature canes have been included, if it was possible to measure the lengths of the joints in the first 20″. It is well known that the lengthening of these joints, once they are formed, is extremely small and may be neglected.[1]

The averages have been obtained in three ways, the *as*, *bs*, etc., of each plant have been averaged separately, the averages for the varieties have been obtained from these, and these latter have been again averaged for the groups

[1] Kuijper, J. De groei van bladschijf, bladscheede on stengel van het suikerriet. *Med. Java Suikerind.*, V., 8, 1915.

(column 1). Secondly, all the *as*, *bs*, etc., of each variety have been averaged, and these variety averages have given those of the group (column 2). Thirdly, all the *as*, *bs*, etc., of each group have been taken together (column 3). It is remarkable how little difference there is in the three resulting sets of figures. There is a steady rise in the average length of joints in every single group, and sometimes a sudden increase between the *bs* and *cs*. The reason for the selection of the two lowest feet of the cane for these measurements has been already given in detail (p. 106).

In the Table, where there are less than four measurements of a branch of one order in a group, the resulting average is placed in brackets, as insufficiently reliable for the group average. Such figures are however included in the total summation at the foot of the Table. If less than 20″ can be measured, the cane is rejected as immature. The joints of runners are omitted and the lengths of joints are not measured until the short-jointed portion following the runner is passed. If moth-borer or other injury is noted as reducing the length of the joints above it, the cane is rejected; this is judged by comparison with other branches of the same order in the same plant.

Average length of joints (above basal part) in the first 2′, in inches.

Groups	No. of varieties	Number of branches of different orders						All the branches of the same order taken together																	
								In each plant						In each variety						In each group					
		a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*
Saretha	6	29	109	77	20	(2)	...	2·1	2·8	3·3	3·5	(3·0)	...	2·1	2·8	3·3	3·6	(3·0)	...	2·2	2·9	3·4	3·6	(3·0)	...
Sunnabile	6	35	101	60	(2)	...	...	1·9	2·3	2·7	(2·5)	...	...	1·9	2·3	2·9	(2·5)	...	...	1·9	2·4	3·0	(2·5)	...	...
Pansahi	6	20	69	75	32	...	...	2·2	2·9	3·6	4·4	...	...	2·2	2·8	3·6	4·5	...	...	2·2	2·8	3·6	4·5	...	...
Nargori	6	19	71	72	(1)	...	...	2·0	2·5	3·6	(3·5)	...	...	2·0	2·6	3·7	(3·5)	...	...	2·1	2·6	3·8	(3·5)	...	...
Mungo	6	38	139	102	28	(1)	...	1·7	2·0	2·1	2·5	(1·8)	...	1·7	2·0	2·1	2·5	(1·8)	...	1·7	2·0	2·2	2·8	(1·8)	...
Unclassified indigenous ...	6	31	94	48	4	...	...	2·2	2·9	3·2	3·8	...	...	2·2	2·9	3·2	3·8	...	...	2·1	2·9	3·3	4·1	...	...
Rogues	4	14	61	87	49	6	(1)	2·5	3·4	3·8	3·8	3·9	(3·9)	2·5	3·4	3·7	3·8	3·9	(3·9)	2·6	3·4	3·7	3·8	4·0	(3·9)
Crosses	2	8	29	25	(1)	...	...	2·7	3·1	3·4	(3·8)	...	...	2·7	3·1	3·2	(3·8)	...	...	2·7	3·1	3·4	(3·8)	...	...
Thick canes ...	6	24	51	42	6	...	...	1·8	2·3	2·8	3·0	...	...	1·8	2·4	2·8	3·0	...	...	1·9	2·4	2·7	2·7	...	...
Red Mauritius at Nellikuppam	1	30	89	74	23	(3)	...	2·6	3·1	3·3	3·3	(4·5)	...	2·6	3·1	3·2	3·3	(4·2)	...	2·6	3·1	3·4	3·4	(4·2)	...
Saccharum spontaneum	3	17	63	86	34	7	(2)	2·7	3·5	3·9	4·0	4·4	(4·8)	2·7	3·5	3·8	4·0	4·4	(4·8)	2·7	3·4	3·6	4·1	4·5	(4·8)
Saccharum arundinaceum	1	3	16	26	22	18	...	2·1	3·3	5·2	5·8	6·5	...	2·1	3·2	5·0	5·7	6·4	...	2·1	3·2	5·0	5·7	6·4	...
Average of all the groups	...	...	...	...	...	...	...	2·2	2·8	3·4	3·7	4·0	4·3	2·2	2·8	3·4	3·8	3·9	4·3	2·2	2·8	3·4	3·7	4·0	4·3

(6) Average thickness of branches of different orders.

As we pass from the main shoots to branches of higher orders, we note, in the dissections, a steady increase in the thickness of the canes. This is not to be wondered at, if we regard each shoot as being furnished with a certain amount of energy of growth. Much of this energy is used up in the main shoot in its change from the infinitesimal stem of the young seedling to a cane of definite thickness. The branches, on the other hand, not only are thicker at the start, but pass through their forming process much more rapidly, and it is to be expected that, before their energy wanes, stronger, thicker canes will be produced.

To compare the thickness of the canes, all have been measured in each plant at about 2′ from the base, where it is reasonable to suppose that the cane has completed its growth in thickness. The measurements were made by calipers in the lateral plane, thus ruling out the ovalness of some varieties, the longer diameter usually occurring in the median plane or that in which the buds lie. The markings on the calipers are in mm., and the results are accordingly given in the metric system. The following are the average thicknesses, in mm., of the main stem and its branches of different degree, in all the groups dissected, *a* 177, *b* 187, *c* 207, *d* 228, *e* 219, *f* 88. The last two figures are not true averages, *f* only occurring in the thinnest form, namely, *Saccharum spontaneum*, and *e* being absent in the Thick canes, Sunnabile, Nargori, Unclassified indigenous and Crosses, in all of which groups the branches which are present show markedly rapid increases. As in the case of the average length of joints, there is a distinct advance from *a* to *b*, but there is a much greater one from *b* to *c*. In the main groups of indigenous Indian canes, there is less difference between the *as* and *bs*. This, as has been noted elsewhere, may be put down to several causes. In the first place, both are formed at a very early stage of the plant's growth—before the general elongating stage has been reached—the plant is small and thin and has comparatively few roots and leaves. In the second place, cases are not infrequently met with in which, *as* having died, one or more of the *bs* become facultative *as*, and the energies of these are devoted rather to branching than to increase in thickness. Thirdly, there are more *bs* on an *a* than *cs* on a *b*, and, as we have seen, this leads to a tailing off of the later-formed *bs*, when the energy of the main shoot is waning (*cf.* p. 107). Lastly, other irregularities occur owing to the deaths of *as* and the consequent relative numbers of *as* and *bs* in a plant. Thus, in *Kharwi*, the thinnest of the Mungo group, 3 *as* and 19 *bs* were measured, whereas in *Hemja*, the thickest cane in the group, there are 15 *as* and 27 *bs*. In taking

all the *a*s and all the *b*s of the group, we thus find that the latter are penalized as to average thickness. But the fact remains, whatever its cause may be, that there is often little difference between the thickness of the main shoot and its immediate branches. And, in dividing up the canes in a clump, both must be classed as early in their general character. The *c*s and *d*s are sharply separated off from the *a*s and *b*s as thick, late canes, and can be readily picked out at harvest by this and other characters.

In the Thick cane group there is a curious exception. While the six varieties examined at Coimbatore and the dry land canes at Nellikuppam show a considerable increase in thickness of the *b*s over the *a*s, this is not the case in the *wet land* plants at the latter place. In these the *a*s are the thickest and there is a general decrease in thickness as we pass to the higher branchings. The *Red Mauritius* at the Cane-breeding Station (and indeed at Nellikuppam on the dry land) are more or less in line with the other varieties. The figures for *Red Mauritius* on the farm, for instance, are *a* 270, *b* 312, *c* 347. We may, in the absence of any further light on the case, merely record the fact here and regard it as an exception which may indicate some peculiarity in wet land conditions.

Average thickness of cane at 2′ from the base, in mm.

Groups	ALL THE BRANCHES OF THE SAME ORDER TAKEN TOGETHER															
	In each plant						In each variety					In each group				
	a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*
Saretha	159	166	178	192	204	...	159	164	174	194	204	160	166	175	188	204
Pansahi	166	166	189	223	284	.	166	165	185	224	284	166	165	185	224	224
Mungo	187	190	210	204	224	...	187	191	209	207	224	196	193	204	204	224
Sunnabile	189	192	209	262	...	...	189	190	208	262	...	186	188	220	262	...
Nargori	151	156	175	213	...	...	152	156	171	211	...	150	154	167	207	...
Thick canes	263	282	298	345	...	.	...	..	...	...	..	...	...		...	...
Red Mauritius, Nellikuppam Dry land	294	304	305	299	314	...	...	..	...	...	..	...	...	...	...	...
" " Wet land	290	274	261	270	268	...		.	...		...	...	...	...	...	...
Unclassified indigenous	164	173	208	251	...	...	.	...	...		...	...	...	...	...	...
Rogues	170	196	211	210	215	...		...	..	...	..	...	..		...	...
Crosses, Vellai × Saccharum spontaneum	158	177	231	.	...	...		...		...	...	...	...	...	...	...
Saccharum spontaneum	73	77	83	88	79	88	.	...	..	..	...	..	...	...	...	...
Saccharum arundinaceum	153	172	209	237	237	...	...	..	...	...	...	...	...	...	...	...
Average of all the groups	177	187	207	228	219	88	...	..	...	...	...	...	...	..	..	...

The work of measuring the thickness of the cane branches of different orders has not always been altogether simple, and has given rise to a series of

"side-issues." Such are, the not infrequent thickening upwards of the early canes and narrowing upwards of late ones; the sometimes enormous thickness at the base of late canes, especially within the region of curvature; the ovalness of some canes and the tereteness of others, and, lastly, the curious case in a few varieties where this ovalness is very pronounced, but in the lateral instead of the median plane, a general flattening of the stem at the base soon to give way to normal tereteness. But these deviations have little or no effect on the general increase in thickness as we proceed to branches of higher order.

Summarizing the results recorded in the last few pages, we see that there is a marked difference between the early and late formed stems in the sugarcane plant. The main shoot has a longer basal portion than its branches, but, owing chiefly to curvature, this portion becomes longer again in the branches of the second and third orders. The average length of joints in the lower part of the cane is less in the main shoot than its branches, and in these again than in the branches of higher orders. With few exceptions the same holds good of the thickness of the cane. For the separation of the canes in a clump, we thus have a series of characters whereby we can distinguish the early and late canes, without the necessity of the tedious process of dissection, there being a marked contrast between the *a*s and *b*s, on the one hand, and the *c*s and *d*s on the other, differences which are so striking that we can with comparative certainty apply the test to the general mass of canes belonging to one variety in the mill yard, and by this means are in a position to make further studies on the milling properties and sugar content of the branches of different order.

(7) Rate of maturing in different varieties and groups.

In passing through the various plots of cane varieties growing on the farm, it is at once obvious that, in the early stages, there is a great difference in the rate of cane formation. While some, like *Saretha*, show cane formation very early, others, like *Dhor*, grow very slowly at first, and do not show any canes for months afterwards. This difference is largely cloaked in North Indian canes by the persistence of the leaf sheaths, but the swelling canes often split these at the base while still attached, and it is quite easy to strip off one or two where this is not the case. But it is difficult to place this difference before the reader, and various attempts have been made, as will be seen below, to make it clearer. There were comparatively few dissections among young canes in the 1916-17 crop, but the results were sufficiently distinctive to make it desirable to extend the series to all the indigenous classes. Two clumps

were accordingly taken for each of the varieties in the dissection plot and these were examined at 3–5 months from planting. The more rapidly maturing groups were taken first, as explained on p. 112. Thus, the Saretha group was examined 106–112 days after planting, Pansahi 113–120, Nargori 120–126, Mungo 126–132, Sunnabile 133–143, and Thick canes 149–152. These were the main groups it was desired to compare. The wild Saccharums, of which one species showed poor accommodation to the cultivated land, were examined at 120–156 days, while the Unclassified indigenous canes, the Crosses and Rogues, being less important, were taken at the end of the series. It transpired that the arrangement was not ideal; the last named varieties should have been dissected earlier, and certain other alterations would have been desirable. This varying age of the plants dissected has introduced complications and must be held in view in the comparisons. In two cases, the early development was so poor that additional clumps were dissected at the end of the period, and a study of the results obtained will give some idea as to the rapidity of change at this stage of growth. *Dhor* was dissected at 142 and 156 and *Khari* at 110 and 156 days, namely, the beginning and the end of the work. The following table gives the canes and shoots formed per clump in these two varieties at the dates given :—

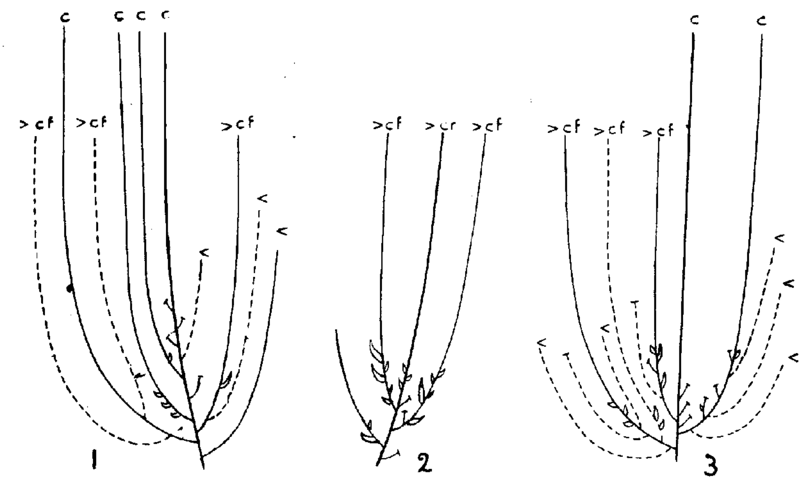
Dhor	.. 2	clumps with	4	plants	142	days old	3·0 canes	2·0 shoots
	.. 2	,, ,,	4	,,	156	,, ,,	5·3 ,,	2·5 ,,
Khari	.. 2	clumps with	6	plants	110	days old	3·5 canes	21 shoots
	.. 2	,, ,,	7	,,	156	,, ,,	14·0 ,,	7 ,,

The word "canes" in the list indicates cane-forming shoots, and this is judged by the presence of hardened rind in one or more of the basal joints. In the diagrams prepared from the dissections, such cane-forming shoots are indicated by the bases being in ink, the rest of the diagrams being in pencil. Green shoots, not cane-forming, are simply classed as shoots and burst buds and deaths are added as usual. A further distinction is introduced in all the shoots, whether cane-forming or not, in that they are separated into two classes, according as they were over or under 3′ in length, and this is indicated in the diagrams by the signs $>$ and $<$, as well as the general length of the line for the branch. All the branches are separated, as usual, into *a*s, *b*s, *c*s, etc. It is obvious that, from a consideration of such a diagram and the formula describing it, a very fair idea can be obtained as to the stage of development of any plant or clump. An example for each group is given in the figures on Plate XIX, where, however, the pencil marks are omitted, full grown shoots are marked c, and half grown,

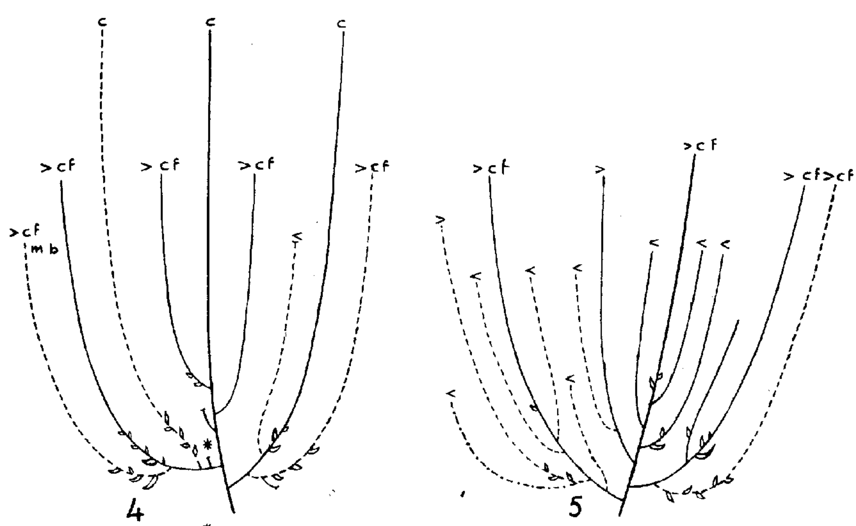
cane-forming shoots cf. The other conventions are those adopted in the diagrams of full grown plants.

Some 275 plants were dissected in 1917-18, and diagrams recorded of their branching systems. These have been averaged according to variety and group, but the results, although generally illuminating, show certain incongruities, obviously requiring explanation. Thus, *Dhaulu*, *Naanal* and *Mojorah* showed enormous and rapid development, which would hardly be expected in the Sunnabile group. It was observed that each of the six clumps dissected in these varieties consisted of a single plant, the two other buds of the set not having germinated, and it is obviously unsafe to compare such single plants with those formed two or three together. On the other hand, in the Mungo group, owing to the closeness of the joints, as many as 7 or, in one case, 11 plants arose from one set, and these naturally showed, on the average, very few branches (Pl. XVI). The whole series was therefore again averaged, this time as to the numbers of canes, shoots, etc., per clump or "hole," and this gave much more satisfactory results.

It was soon observed that there were great variations in the development of the members of certain groups and it becomes doubtful if the six varieties selected suitably represent them. Owing to its rapid growth, the first series dissected was the Saretha group, and it was obvious that *Khari*, *Ganda Cheni* and *Hullu Kabbu* were much behind the rest, although it was known that *Chin* and *Saretha* did not grow well on the farm, while *Cheni* and *Hullu* were quite at home. This emphasizes the subdivision made in this group in Memoir III, into the Brown or Katha and the Green or Mesangan sections, as the same subdivision is seen in the rate of maturing. Less equal subdivisions show themselves in the Sunnabile group where *Dhor* and *Sunnabile* were much behind the rest, in the Mungo group where *Kharwi* shows as great a difference in the opposite direction from its companions, and in the Thick canes where the possibly indigenous *Magh* and *Vendamukhi* are considerably behind *Java*, *Yerra* and *Red Mauritius*. The groups in the table are arranged in the order of dissection.



Saretha (112 days old) Dhor (156 days old) Pansahi (113 days old)



Nargori (126 days old) Kuswar (127 days old)

Diagrams of branching in plants 3-4 months old, in the five groups of indigenous Indian canes. These give a general idea of the conventions used in the 275 diagrams prepared and also give some idea of the relative rate of cane formation in the different groups.

Analysis of clumps in different groups to compare their rate of maturing, 1917-18.

	No. of clumps	Days old	CANE-FORMING SHOOTS (>+<)					SHOOTS NOT CANE-FORMING (>+<)					BURST BUDS					DEATHS					RUNNERS
			a	*b*	*c*	*d*	Total	*a*	*b*	*c*	*d*	Total	*b*	*c*	*d*	*e*	Total	*a*	*b*	*c*	*d*	Total	
Saretha Green	8	108	1·7+0	2·5+0	0·2+0	...	4·3+0	...	1·7+2·3	1+9·2	0+0·5	2·8+12	0·8	6·5	2·7	...	10	...	1·8	2·0	0·5	4·3	0·5
Saretha Brown	6	110	2·7+0	8·0+0	3·2+0·2	0·2+0	14+0·2	...	0·8+2·8	0·7+4·3	0+0·2	1·5+7·3	1·3	7·3	2·0	...	10·7	...	2·5	3·2	1·5	7·2	0·7
Pansahi ...	12	116	2·2+0	6·7+0·1	2·8+0	0+0·2	11·7+0·2	...	0·2+2·3	0·2+4·7	0·1+7·4	0·5+8·4	0·6	15·8	5	0·6	22	0·1	1·4	2·2	1·2	5·0	0·3
Nargori ...	12	123	2·2+0	6·5+0·3	1·6+0·1	...	10·2+0·4	...	0·1+1·8	0+1·2	...	0·1+3	7·5	10·9	1·8	...	20·2	0·2	2·2	3·7	0·3	6·4	0
Mungo ...	12	129	2·8+0·2	6·1+0·7	3·6+0·7	0·2+0·4	12·7+2	0·2+0·2	1·1+7·9	0·7+10·5	0+2·5	2·1+21·4	6·7	25·3	18·9	2·8	53·8	0·6	2·8	3·2	1·1	7·7	0
Sunnabile	14	138	1·3+0·7	3·8+2·8	2+1·1	0·1+0·3	7·2+5	...	0·2+1·4	0+1·3	...	0·2+2·7	8·4	27·3	4·3	0·6	40·7	0·2	2·9	2·2	0·6	5·8	0
Unclassified indigenous	12	145	1·9+0·6	4·1+5·5	0·6+2·2	0+0·2	6·6+8·5	...	0+0·3	0+0·4	...	0+0·7	7·4	28	4·2	0·1	39·7	0·2	3·5	5·3	0·8	7·8	0
Thick ...	10	150	1·0+0·8	1·1+5·7	0+1·5	...	2·1+8·1	...	0+2·7	0+2·4	...	0+5·1	5	23·7	3·1	...	31·7	...	4·1	6·2	0·4	10·7	0
Rogues ...	4	154	0·5+2·5	1+12	0+12	0+1	2+27·5	...	0+4	0+9·5	...	0+13·5	5	14	5	...	24	...	8·5	11	0·5	20	0
Crosses, Vellai × Saccharum spontaneum	4	156	2·5+0	7+2·7	2·5+4·7	...	14+7·5	...	0+2·5	0+4·2	...	0+6·7	0·5	9·2	10·2	...	20	...	2·7	5·7	3·5	12	0
Saccharum spontaneum	4	134	0·5+1·2	1·2+4·5	0·5+5	0+0·5	2·2+11·2	...	0+2	0+2	0+0·7e	0+4·7	0·7	1·0	0·5	...	2·2	0·2	3·2	5·2	0·5	9·2	2·2

With this table before us, the question naturally arises as to how we can use it for determining the rate of maturing. We may do so in a variety of ways. We may compare the average number of canes per clump in each group or section; we may calculate the number of canes in the total number of shoots; we may contrast the canes over 3′ with those under that length; we may do the same with the total number of shoots; and, lastly, we may compare the number of cane-forming shoots at 3–5 months with the average number formed at harvest in the same plots. There are, however, objections to all of these methods, even when the relative ages of the plants at the time of dissection have been allowed for. In the first, we neglect the inherent tillering capacity of the different varieties, in the second the Sunnabile and Nargori groups are favoured because of the very small number of small shoots which are developed in them, in the third and fourth we discriminate in favour of forms with long canes such as *Saretha* as against the short-caned forms such as *Mungo,* and in the last we neglect the habitual deaths which take place during the life of the plant and which are so numerous in the Thick canes, for instance, that there are actually more canes forming per clump at 5 months than there are at harvest. But something may be learnt, with proper safeguards, from a study in each of these directions, and the results have been grouped in the following table. In this, besides the averages for each group, the brown and green sections of Saretha are given separately, in the Sunnabile group *Dhor* and *Sunnabile* are taken as a sub-section (Dhor) and compared with the rest (Dhaulu), and *Kharui* is similarly treated separately in the Mungo group. The other groups appear to be more homogeneous, but, in the Thick canes, *Magh* and *Vendamukhi,* as noted above, are very much behind *Yerra, Java* and *Red Mauritius.* In each of the arrangements 1–5, the groups are placed in order of development from top to bottom.

Arrangements of the different groups of cane dissected according to different evidences of relative maturing (*see* p. 130).

CANES PER CLUMP		CANES TO TOTAL SHOOTS			CANES > TO < 3′			TOTAL SHOOTS > TO < 3′			CANES AT 4 MONTHS TO CANES AT HARVEST		
Arrangement No. 1	Canes	Arrangement No. 2	Canes	Total shoots	Arrangement No. 3	> 3′	> 3′	Arrangement No. 4	> 3′	< 3′	Arrangement No 5	4 months	Harvest
Sunnabile (Dhaulu)	15·2	Unclassified indigenous	15·1	15·8	Saretha (Green)	4·3	0	Nargori ...	10·3	3·4	Thick ...	12·4	8·7
Unclassified indigenous	15·1	Sunnabile (Dhaulu)	15·2	18·1	Saretha ...	9·1	0·1	Saretha (Brown)	15·5	7·5	Sunnabile (Dhaulu)	15·3	18·0
Saretha (Brown)	14·2	Nargori ...	10·6	13·7	Saretha (Brown)	14·0	0·2	Mungo (Kharwi)	25·0	13·5	Sunnabile ...	12·2	17·1
Mungo (Kharwi)	13·7	Sunnabile ..	12·2	15·1	Pansahi ...	11·7	0·2	Sunnabile (Dhaulu)	10·6	7·5	Saretha (Brown)	14·2	24·0
Saccharum spontaneum	13·2	Saccharum spontaneum	17·4	19·1	Nargori ...	10·2	0·4	Pansahi ...	12·2	8·6	Unclassified indigenous	15·1	25·0
Sunnabile ...	12·2	Thick ...	10·2	15·2	Mungo (Kharwi)	24·5	2·0	Saretha ...	11·3	7·7	Nargori ...	10·6	17·0
Pansahi ...	11·9	Sunnabile (Dhor)	6·2	9·2	Mungo ...	12·7	2·0	Sunnabile ...	7·7	7·7	Pansahi ...	11·9	21·0
Nargori ...	10·6	Mungo (Kharwi)	26·7	28·7	Mungo (rest) ...	10·2	2·0	Unclassified indigenous	6·6	9·2	Sunnabile (Dhor)	6·2	15·0
Thick canes ...	10·2	Saretha (Brown)	14·2	23·0	Sunnabile (Dhaulu)	10·4	4·9	Mungo ...	14·8	23·4	Saretha ...	9·2	23·0
Saretha ...	9·2	Pansahi ...	11·9	20·8	Sunnabile ...	7·2	5·0	Saretha (Green)	7·1	12·0	Mungo (Kharwi)	13·7	37·0
Mungo ...	7·3	Saretha ...	9·2	21·0	Unclassified indigenous	6·6	8·5	Mungo (rest) ...	12·6	25·3	Saccharum spontaneum	13·2	41·0
Sunnabile (Dhor)	6·2	Mungo ...	14·7	38·2	Thick ...	2·1	8·1	Thick ...	2·1	13·2	Mungo ...	7·3	28·4
Mungo (rest) ...	6·1	Mungo (rest) ...	12·2	27·4	Saccharum spontaneum	2·2	11·2	Saccharum spontaneum	2·2	15·9	Mungo (rest) ...	6·1	27·0
Saretha (Green)	4·3	Saretha (Green)	4·3	19·1	Sunnabile (Dhor)	1·0	5·2	Sunnabile (Dhor)	1·0	8·2	Saretha (Green)	4·3	22·0

From a study of this table we get the following order of development as judged by the various comparisons in the columns 1–5. Sunnabile (Dhaulu), Saretha (Brown), Nargori, Unclassified indigenous, Sunnabile, Mungo (Kharwi), Pansahi, Saretha, Thick canes, *Saccharum spontaneum*, Mungo, Saretha (Green), Sunnabile (Dhor), Mungo (rest). But we have, in addition, to consider the ages of the plants dissected. It is thus seen that the position of Sunnabile (Dhaulu) at the head of the table must be qualified, firstly, by the fact that in these members of the section, only a single plant developed in each clump, presumably assisting in rapid maturing, and, secondly, that the dissections were made late (4 weeks after the Brown section of Saretha), because of the slow development of *Dhor* and *Sunnabile.* Saretha (Brown) is obviously the quickest of all in maturing. Similarly, the juxtaposition of the Saretha and Thick cane groups, examined at 109 and 150 days respectively, indicates that the latter are much later in development than the former. So the Mungo group, excepting *Kharwi*, are very late indeed, being near the bottom of the list, although dissected moderately late (129 days). But the method is interesting, although unsatisfactory for generalizations.

The only way in which these various defects can be avoided is to take the groups and sections separately and compare them with the rest in the following manner. Saretha (Brown) is ahead of Pansahi, although examined a week earlier. There are more canes formed, and, in these, there is a slightly larger proportion of canes over than under 3′ in length; there are practically the same number of immature shoots, but in these too there is a slight excess of the shoots over 3′ long in Saretha; there are only half the number of buds and there are slightly more deaths. If the tillering power of the two groups is considered, there is a larger proportion of canes formed in Saretha in 110 days than in Pansahi in 116. It may therefore be safely concluded that the Brown section of the Saretha group is earlier in its development on the farm than the Pansahi group. The same method may be applied all through and, as a result, we can place the groups roughly in the following order:—

Early maturing, Saretha (Brown), Nargori, Pansahi, Saretha, Sunnabile (Dhaulu), Mungo (Kharwi);

Moderately early maturing, Various indigenous, Saretha (Green), *Saccharum spontaneum*, Thick canes;

Late maturing, Sunnabile, Mungo, Mungo (rest) and Sunnabile (Dhor).

The full table of analyses of the different varieties is annexed, the figures in each group being the averages obtained for each clump.

(8) General notes on the characters of the groups and their mode of branching.

It will be impossible within reasonable limits to discuss the many interesting facts observed in the dissections of the cane clumps of the different varieties in each group. The diagrams and measurements of the individual plants are added to the already large mass of notes on the morphology of canes collected in the office files. A few general notes are here given on the characters of branching in each group and a selection has been made of a few more or less typical diagrams and photographs to illustrate its general character. For photographs, we have had to rely entirely on 1916-17 dissections, because, from pressure of work and the high price of materials, we were unable to photograph the dissected plants in the second year. The main shoot *a* can be distinguished in these photographs by a white paper band fastened round it. As the full scheme of diagrams was not developed until 1917-18, it has not always been easy to give the full diagrams of the particular plants photographed, although this has been done where possible. As an instance of the method, Plates XXVIII-XXX may be referred to. In Plate XXVIII, a clump of the dwarf canes of *Hemja*, in the Mungo group, has been photographed as it reached the laboratory; Plate XXIX gives photographs of the four dissected plants in this clump, and in the lower half of Plate XXX the diagrams of the four plants are reproduced. There are few photographs available of the Thick canes, as less attention was paid to this class in the first year, but, besides a dissection of *Java*, a picture is reproduced of a ratooned *Red Mauritius* cane, and its diagram is appended. In the wild Saccharums, photographs are given of *S. Munja*, *S. arundinaceum*, and the two chief varieties of *S. spontaneum* (Pl. XXXIV); further pictures may be found in Plate II of Memoir III and Plate XXI of Memoir II. *Saccharum Narenga* is illustrated on Plates IX and X of Memoir II and needs no repetition. For fuller illustrations of these wild Saccharums, reference may be made to the excellent monograph by Hole in the Indian Forest Memoirs.[1] The diagrams of *Saccharum Munja* and *Saccharum Narenga* are less instructive, in that these species do not form canes in the strict sense, but their grass-like habit may be inferred from the diagrams given on Plate XXXVII, where the " canes " refer to shoots forming solid canes at their bases.

Saretha Group.

The Saretha group is somewhat difficult to describe without going into great detail, as it consists of two well-marked sections, the main characters

[1] Hole, R. S. On some Indian Forest Grasses and their Oecology. *Ind. For. Mem., For. Bot. Ser.*, Vol. I, Part 1, 1911.

of which have been discussed in Memoir III. These sections are separated, in the first place, by having red-brown and green stems at maturity. Of the members dealt with in this paper, *Katha* in the Punjab, and *Chin* and *Saretha* in the western United Provinces belong to the first section; the second section includes *Khari*[1] in Bengal, *Hullu Kabbu* on the western coast of the Peninsula and *Ganda Cheni* in Mysore; the distribution of the two sections is thus seen to be geographical, the northern members being thinner and more primitive. The Green section of the Saretha group appears to approach the Sunnabile group in many particulars. As might be expected, the forms indigenous to the Peninsula are much more at home on the Cane-breeding Station, and this renders the comparison of the two sections, as regards formulæ, difficult. It is probable that the branching of the Red-brown section is more complicated than that in the Green section, but this does not show up very clearly for the reasons given. The rate of cane formation is very much more rapid in the Red-brown section.

The arrangement of the canes in the clump is characterized by irregularity, canes being produced at all angles, with the outer ones often spreading widely or even prostrate. An intricate mass is thus formed, and, as the attachments are very thin and brittle, dissection, especially in the Red-brown section, is very difficult. There are, in most of the varieties, a large number of runners and the spacing of the canes in the clump is due rather to their irregular arrangement and the presence of these runners than to orderly curving of the outer branches, in this character resembling *Saccharum spontaneum*. The canes are long-jointed, knotted and zigzag, and vary little in thickness in different parts of their length, and there is less ovalness than in most other groups[2] (Pls. XX and XXI).

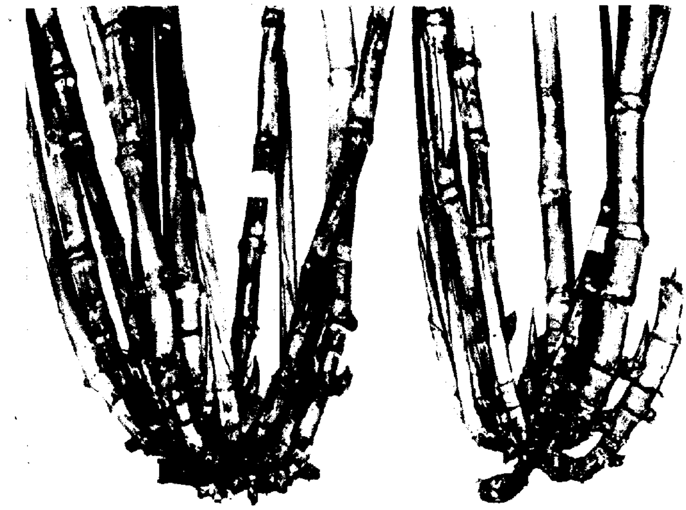
The appended tables give the varietal formulæ, and the average length of basal parts, length of joints in the lower two feet and thickness at two feet from the base. There is, generally, a marked difference between the branches of different orders. Owing to the comparative absence of curvature in the younger branches, the length of the basal part of the cane does not increase rapidly from *b* onwards.

[1] There appear to be several cane varieties included under this name, as in *Baraukha*, *Ketari*, *Chynia*, etc. One *Khari* in our collection is fairly obviously a Pansahi cane.

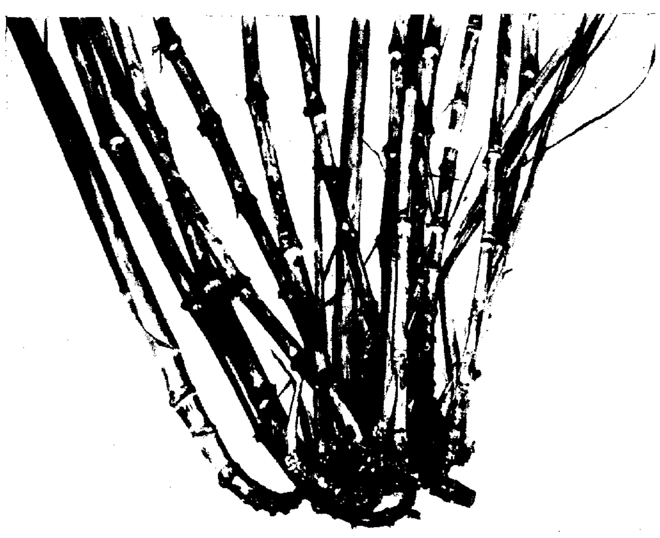
[2] For fuller descriptions of some varieties in this group, *see* Mem. I, where the primitive Punjab forms are described, and Mem. III, where the general characters of the group and its sections are given in some detail.

PLATE XX.

SARETHA GROUP.



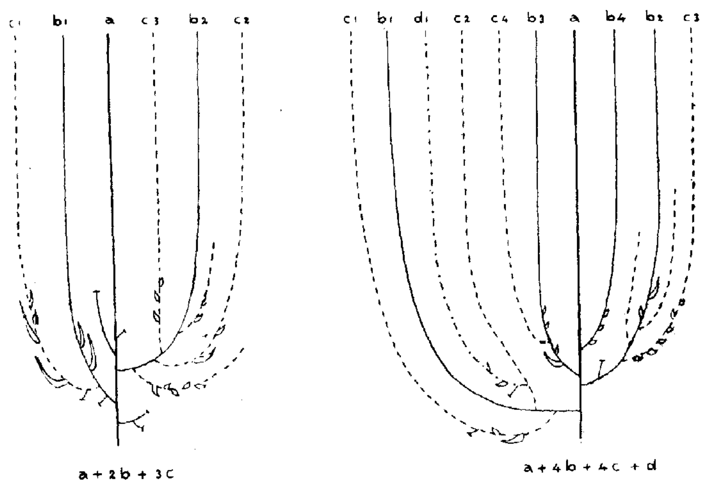
Hullu Kabbu 1916 (8½ months old). One clump with two plants.



Katha 1916 (8½ months old). One of three plants in one clump.

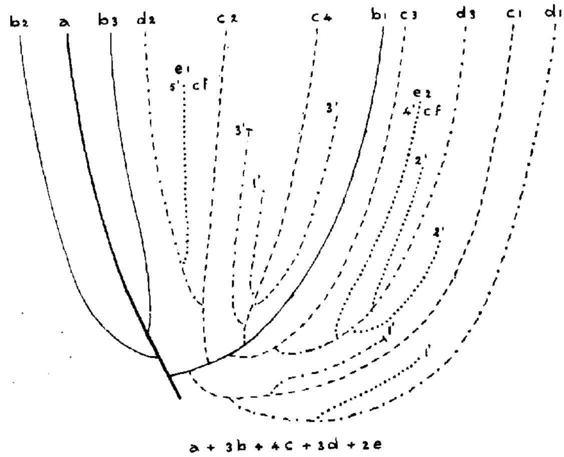
Hullu Kabbu 1916 (8½ months old)

One clump with two plants



Katha 1916 (8½ months old)

One plant out of three in a clump



Diagrams of the branching in the three plants photographed in the previous plate.

FORMULÆ AND MEASUREMENTS IN THE SARETHA GROUP.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected		Canes at harvest							Green shoots					Bursting buds					Dead						Grand Total	Runners
	Clumps	Plants	*a*	*b*	*c*	*d*	*e*	*f*	Total	*b*	*c*	*d*	*e*	*f*	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*		
Chin ...	3	7	0·9	3·0	2·4	1·4	0·1	...	7·9	0·3	2·1	1·6	0·4	0·6	0·1	2·4	3·9	1·0	...	0·1	2·9	3·4	2·6	1·0	...	30·3	0·4
Katha ...	3	9	0·9	3·1	4·3	2·0	0·3	...	10·7	0·4	1·6	1·6	0·6	...	0·7	2·2	3·3	0·3	0·4	0·1	1·1	3·6	1·8	0·9	...	29·3	1·5
Saretha	5	14	0·6	3·2	3·6	0·6	...	...	8·1	0·4	3·5	1·4	0·2	...	0·7	6·1	2·9	1·6	...	0·4	1·9	6·3	1·6	0·1	...	35·2	1·0
Ganda Cheni	3	7	1·0	3·1	3·4	0·9	0·1	0·1	8·6	0·3	1·6	1·1	.	...	0·4	5·0	5·9	2·0	0·3	...	2·0	5·6	5·0	1·3	0·6	39·7	1·2
Hullu Kabbu ...	3	8	0·7	3·5	3·2	1·6	0·4	...	9·5	0·2	1·6	1·0	0·5	...	0·2	4·2	5·0	0·2	...	0·2	1·1	3·0	2·5	0·1	..	29·3	0·2
Khari ...	3	8	0·9	3·1	3·6	0·4	...	...	8·0	...	1·9	1·6	...	...	0·4	4·1	7·6	1·2	..	0·1	4·0	7·5	4·9	0·4	...	41·7	0·4
Average	...	...	0·7	3·2	3·4	1·1	0·1	...	8·8	0·3	2·2	1·4	0·3	0·1	0·5	4·2	4·5	1·1	0·1	0·2	2·1	5·0	2·9	0·6	0·1	34·3	0·8

Group formulæ Canes at harvest 1 : 3 : 3 : 1 The whole branching system 1 : 6 : 15 : 10 : 2 Runners 1

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

Variety	Average length of basal part, in inches						Average length of joints in the first two feet										Average thickness of canes at two feet from base									
							Number of canes measured					Average length, in inches					Number of canes measured					Average thickness, in mm.				
	a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*
Chin	3·3	1·8	2·3	3·0	2·7	...	4	12	6	2	1	2·0	2·5	2·9	2·9	2·5	5	11	6	2	1	124	132	140	152	157
Katha	3·8	2·2	2·0	1·4	...	...	5	19	12	...	...	2·2	2·6	3·0	...	..	5	19	10	...	...	136	135	140	...	...
Saretha	2·8	1·9	2·5	1·7	...	...	7	31	19	6	...	2·5	3·2	3·3	3·2	...	7	35	19	5	...	160	167	174	181	...
Ganda Cheni ...	3·2	2·0	1·8	2·2	1·5	1·5	5	17	15	5	1	2·2	3·0	3·0	3·6	3·5	5	16	12	5	1	197	200	222	225	252
Hullu Kabbu .	2·5	1·8	2·5	1·9	2·7	...	4	12	14	6	.	2·0	3·0	3·9	3·9	..	3	12	11	2	...	175	185	203	207	...
Khari	3·3	2·1	1·7	5·0	..	...	4	18	11	1	...	1·8	2·7	3·5	3·9	...	4	16	7	1	...	162	175	187	193	...
Average ...	3·1	2·0	2·1	2·5	2·3	1·5	...	...		...	...	2·1	2·8	3·3	3·5	3·0	..	...	..	...	...	159	166	178	192	204

Pansahi Group.

The Pansahi group is very homogeneous, and no subdivisions have as yet been observed in it. The geographical range is fairly wide, but only in an east and west direction. No examples have as yet been received from the Peninsula area, although members of the group have been met with in every province from the Punjab to Burma. The greatest development of the group is perhaps in Bihar, but *Kahu* is found in the Punjab and *Thin Moulmein* in Burma. The group is of especial interest in that it contains *ganna* canes, that is, those intermediate between the thin, hardy *ukh* canes and the *paunda* or thick chewing class; also that it includes the *Yuba*, which is the chief variety grown in Natal. This cane is of special interest in that it appears to have reached Natal from Brazil where it is regarded as a "country" cane.[1] It is quite conceivable therefore that it is the cane taken from the Punjab by Alexander the Great in 326 B. C.[2]

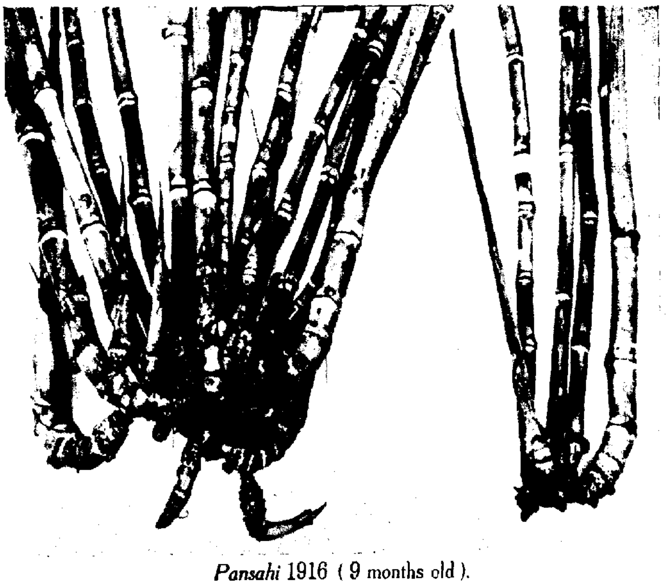
Cane formation takes place early, and the varieties all grow well at Coimbatore; they are very free growing and appear to be little inconvenienced by the rather tenacious, saltish land. In habit, they are regularly cup-shaped, and the leaves fall in a wide curve all round the centre. In branching, they are often very symmetrical (*cf.* fig. 1, p. 157, Mem. III), the inner canes being straight, and the succeeding ones more or less curved according to their distance from the centre; strong curves are found in the later canes, and runners are not uncommon. The attachments are very firm and thick, making it possible to dissect great portions at a time without separating the branches. In many respects the branching system strikingly reminds one of that of *Saccharum arundinaceum*, although there is no trace of connection with that wild form in the other morphological characters. The canes are fairly straight but the joints, especially in the later canes, are long and markedly zigzag, and the nodes are prominent.[3] The Plate following illustrates the general form in *Maneria* and *Pansahi*, but the diagrams of these are not given, as that in Memoir III, referred to above, will suffice. On the other hand, diagrams are given of *Yuba*, and a remarkably well grown plant of this variety is included. (Pls. XXII and XXIII.)

The length of joint shows great regularity in its increase in the branches of successive orders, and the length of the basal part bears evidence of the strong curvature in the later branches. In thickness, the *a*s and the *b*s are practically equal and differ widely from the *c*s and *d*s, thus dividing the canes of the clump into early and late formed canes, which separation is very characteristic of the group. These points are well brought out in the appended table.

[1] Deerr, Noel. The Origin of the Uba Cane. *International Sugar Journal*, April, 1918, p. 164.
[2] C. A. Barber. The Origin of the Uba Cane. *International Sugar Journal*, September, 1918, p. 706.
[3] For fuller description of a cane of this group, *see* Mem. I, pp. 95–103 and Plates XV, XVI and XIX.

PANSAHI GROUP.

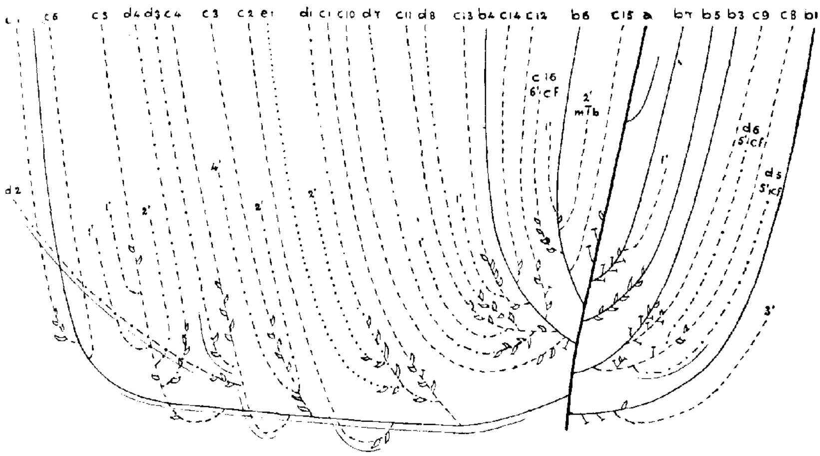
Maneria 1916 (9 months old). A clump with only one plant.



Pansahi 1916 (9 months old).
Two of three plants in one clump: the remaining plant is shown on Plate III, Memoir No. III.

Yuba 1916 (7½ months old)

One clump with two plants. Only the larger plant is drawn.

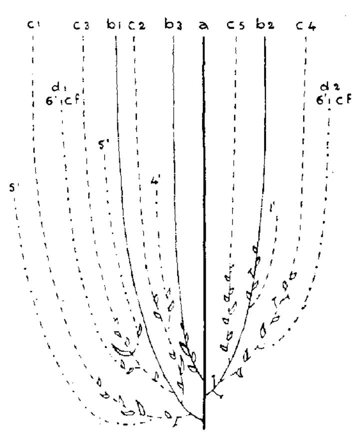


a + 7b + 16c + 8d + e

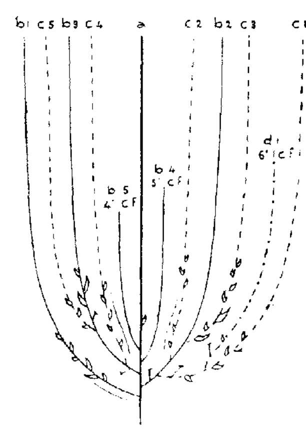
Runners 1b + 2c + 3d

Yuba 1916 (7½ months old)

One clump with two plants



a + 3b + 5c + 2d



a + 5b + 5c + d

Runners 1b + 2c

Diagrams of three *Yuba* plants. The upper diagram is that of an abnormally luxuriant plant, the lower diagrams being more like the normal. A Pansahi diagram is given on p. 157 of Memoir No. III.

Formulæ and Measurements in the Pansahi Group.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected		Canes at harvest						Green shoots				Bursting buds					Deaths					Grand Total	Runners
	Clumps	Plants	*a*	*b*	*c*	*d*	*e*	Total	*b*	*c*	*d*	*e*	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*		
Chynia	2	2	0·5	4·5	5·5	4·0	...	14·5	...	0·5	2·0	1·5	...	6·5	14·5	20·0	...	0·5	1·0	2·5	6·0	1·0	70·5	1·0
Kahu	2	5	0·6	3·0	3·0	1·8	0·4	9·2	...	0·2	1·6	0·4	1·4	4·6	2·5	3·0	...	0·4	2·4	3·2	1·2	0·2	30·3	1·4
Maneria	3	7	0·9	3·4	3·3	1·9	...	9·4	0·1	1·0	0·6	...	1·0	2·9	3·7	0·6	...	0·1	2·1	5·0	3·1	0·3	29·9	2·2
Pansahi	3	8	1·0	1·9	3·9	1·4	0·5	8·5	0·1	0·5	0·4	0·2	0·4	2·2	5·4	2·4	...	...	1·6	2·9	2·0	0·9	27·5	0·2
Sada Khajee ...	2	3	0·7	3·0	3·7	5·0	...	12·0	...	1·3	0·7	1·0	...	3·0	6·3	14·7	...	0·3	1·0	3·3	1·3	0·7	45·6	2·7
Yuba	2	4	1·0	4·5	6·7	2·7	0·2	15·2	0·2	1·5	2·7	0·2	0·7	10·7	25·0	10·2	1·2	...	0·7	4·5	3·2	0·5	76·5	2·2
Average ...	...	...	0·8	3·4	4·3	3·1	0·2	11·5	0·1	0·8	1·3	0·5	0·7	5·0	9·5	8·5	0·2	0·2	1·5	3·6	2·8	0·6	46·7	1·6

Group formulæ Canes at harvest 1 : 3 : 4 : 3 The whole branching system 1 : 6 : 14 : 17 : 7 Runners 2

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

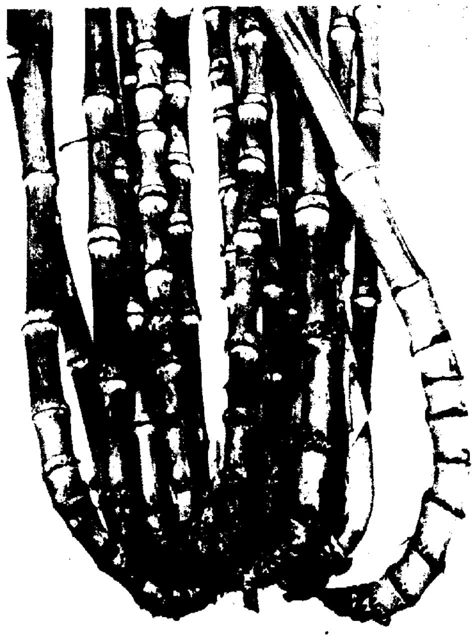
Variety	Average length of basal part, in inches					Average length of joints in the first two feet								Average thickness of canes at two feet from base									
						Number of canes measured				Average length, in inches				Number of canes measured					Average thickness, in mm.				
	a	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*
Chynia	4·0	1·7	2·0	2·5	...	1	8	10	6	2·0	2·8	3·3	3·9	1	8	10	6	...	170	163	178	206	...
Kahu	3·7	1·3	1·9	2·7	2·0	3	13	10	7	2·3	2·9	3·2	4·2	3	13	11	7	...	158	159	184	220	...
Maneria	2·9	2·1	1·9	2·8	...	5	18	10	2	1·9	2·8	3·1	4·2	6	23	17	4	...	168	185	216	269	...
Pansahi	3·2	1·6	2·3	2·5	...	5	8	13	1	2·1	3·1	4·8	5·4	8	17	19	13	...	164	164	207	219	...
Sada Khajee	3·3	2·1	2·1	1·8	...	2	7	11	12	2·3	2·9	3·5	4·6	2	8	11	7	...	173	152	177	215	...
Yuba	3·3	1·7	2·1	1·9	2·0	4	15	21	4	2·5	2·9	3·6	4·0	4	15	18	4	1	166	171	174	212	284
Average	3·4	1·7	2·0	2·4	2·0	...	...	...	...	2·2	2·9	3·6	4·4	...	...	...	...	...	166	166	189	223	284

Nargori Group.

The Nargori group is a very distinct one, being readily separated, among other things, by its curious palm-like habit, a bundle of erect, knotted canes surmounted by a thick bunch of short, broadish leaves, often with a brownish or copper coloured tinge in North India. The group appears to be a primitive one. Its distribution along the foot of the Himalayas is apparently less wide than that of the Pansahi group, as specimens have only been received from Bihar and the United Provinces, but varieties belonging to it have also been received from the south of the Central Provinces, and thus it enters the Peninsula. The varieties collected grow fairly well on the Cane-breeding Station. The canes curve very sharply at the base and quickly assume a vertical direction, and the clump thus takes up little room. The branching is not extended, as can be seen from the formula, and there is a marked absence of runners or irregularities of any kind. The canes are very straight, mostly thin, with well marked bloom bands and always strongly noded. The varieties mature early and there are few shoots or bursting buds at nine months from planting, making the preparation of the cane formula easy. The basal portion of the stem is long, especially in the *as*, where there are a large number of short joints under 1″ in length. The average length of joints increases at first slowly and then rapidly with successive branchings, but there is little difference in thickness between the *as* and the *bs*. This makes it an easy matter to separate the early and late formed canes at harvest, as represented by *as*+*bs* and *cs*+*ds* respectively. In two varieties measured, it would seem that the *as* are actually thicker than the *bs* and the figures are equal in a third variety. (Pls. XXIV and XXV.)

NARGORI GROUP.

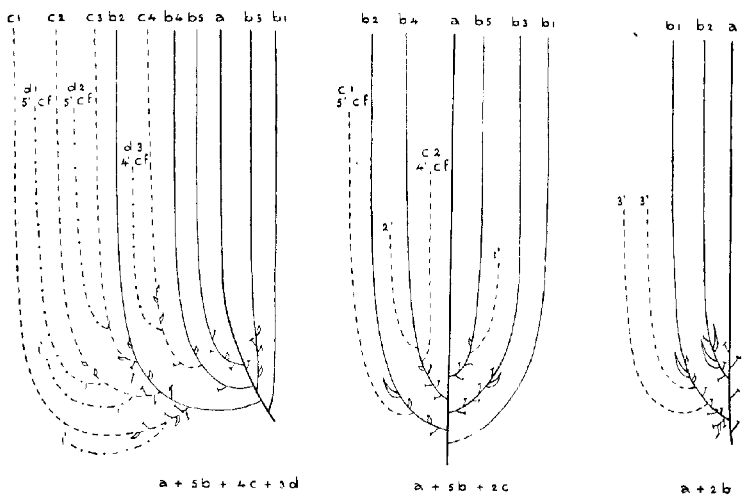
Sararoo 1916 (9 months old). One clump with three plants.



Kewali 1916 (9 months old). Clump with only one plant.

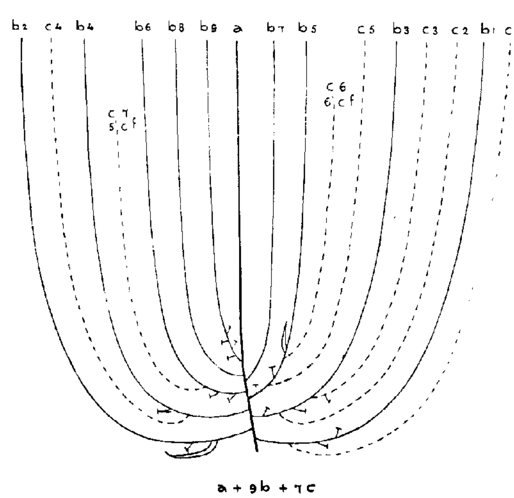
Sararoo 1916 (9 months old)

One clump with three plants



Kewali 1916 (9 months old)

One clump with only one plant



The diagrams of branching of the four plants in the preceding plate.

FORMULÆ AND MEASUREMENTS IN THE NARGORI GROUP.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected		Canes at harvest					Green shoots			Bursting buds				Deaths				Grand Total	Runners
	Clumps	Plants	a	b	c	d	Total	b	c	d	b	c	d	e	a	b	c	d		
Baraukha	2	4	0·7	2·5	2·7	..	6·0	...	0·2	.	0·7	6·0	0·2	...	0·3	1·7	2·0	...	17·1	0·2
Katai	2	6	1·0	3·4	2·8	...	5·2	...	0·4	...	0·4	4·0	0·4	...	—	2·4	4·6	...	17·4	0·3
Kewali	3	6	0·7	4·0	2·7	...	7·5	0·3	0·3	...	0·3	4·2	0·3	...	0·4	1·0	3·5	0·2	19·2	0·0
Nargori	3	7	0·7	2·6	4·1	1·1	8·6	...	1·5	0·3	...	0·7	1·7	0·1	0·3	2·0	8·9	3·9	26·8	0·0
Newra	2	5	0·8	2·0	5·2	...	8·0	...	...	..	0·6	1·4	4·8	..	0·2	1·6	0·4	...	17·0	0·0
Sararoo	3	6	0·8	4·0	3·2	0·7	8·7	...	1·5	0·7	..	4·0	5·3	0·2	0·2	1·3	6·2	2·5	30·6	0·0
Average ...	...	...	0·8	3·1	3·5	0·3	7·8	...	0·6	0·2	0·3	3·4	2·1	...	0·2	1·7	4·3	1·1	21·3	0·1

Group formulæ   Canes at harvest   1 : 3 : 3   The whole branching system 1 : 5 : 12 : 4   Runners 0

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

Variety	Average length of basal part, in inches				Average length of joints in the first two feet: Number of canes measured				Average length of joints in the first two feet: Average length, in inches				Average thickness of canes at two feet from base: Number of canes measured				Average thickness of canes at two feet from base: Average thickness, in mm.			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
Baraukha ...	4·4	1·9	2·3	...	3	10	6		1·8	2·6	3·4	...	3	7	2	...	166	162	173	...
Katai	3·2	1·8	2·6	...	5	17	3	...	2·5	3·5	4·3	...	5	17	13	...	173	163	172	...
Kewali	6·3	2·2	2·3	.	3	14	3		1·5	2·3	3·7	...	3	14	5	...	168	168	181	
Nargori	5·2	2·9	2·2	2·1	2	9	18	1	2·0	1·9	3·1	3·5	5	16	12	4	129	143	171	209
Newra	3·3	1·6	2·3	...	4	9	22	...	2·2	2·6	4·2	...	4	9	8	...	138	159	170	...
Sararoo	5·6	2·1	2·2	...	2	12	10		1·9	2·2	3·7	...	5	22	12	1	135	138	181	218
Average ...	4·7	2·1	2·3	2·1	...	...		...	2·0	2·5	3·6	3·5	...	...	...	...	151	156	175	213

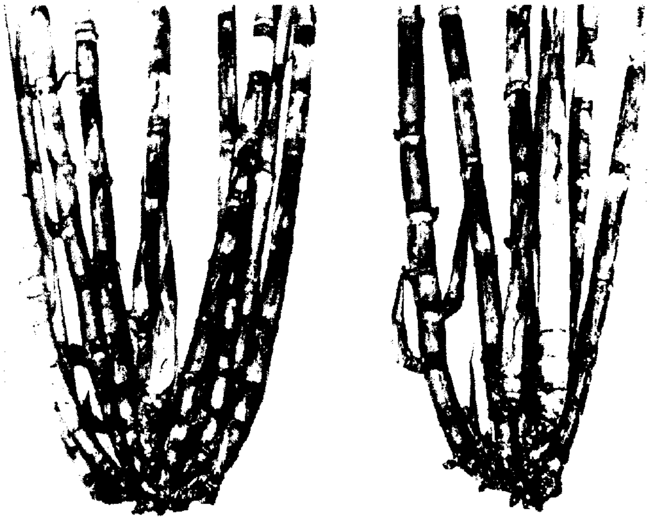
Sunnabile Group.

The Sunnabile group, although widely distributed over India, from the Punjab to Assam and Madras, and including canes of all degrees of thickness, is far more homogeneous than the Saretha, as has been fully discussed in Mem. III. But here, too, the geographical distribution appears to have left its mark on the branching system. *Bansa* from Western Bengal appears to be a more vigorous variety than the rest, and *Dhaulu* from the Punjab and *Mojorah* in Assam are also heavier tillerers than the other three examined. These latter are, as pointed out on page 111, Peninsula forms, *Dhor* from the Central Provinces, *Sunnabile* from Bombay and *Naanal* from Madras. Nevertheless, the group, as a whole, is marked by rather sparse branching and a restricted formula, resembling Nargori and approaching the Thick cane group in this respect. The clumps are close and upright and the leaf tips are usually erect. Runners are absent and there are usually many large, white, clawed buds in the dissections. Curving is moderate and merely such as is necessary to bring the canes quickly into parallelism. The canes are soft and often white in colour. The plants are much affected by mealy bug on the farm, possibly due to the slowness of growth and softness of the rind. The general appearance of the dissected clump is one of smoothness and regularity, as can be seen in the photographs, the canes being straight and regular and without any prominent nodes, in these respects resembling varieties of the Mungo group. There is less difference than usual in the canes of different orders in all respects and it would be difficult to separate the early and late canes at harvest.[1] (Pls. XXVI and XXVII.)

[1] For fuller details regarding the characters of this group, *see* Mem. III, where the connecting characters are tabulated and contrasted with those of the Saretha series.

SUNNABILE GROUP.

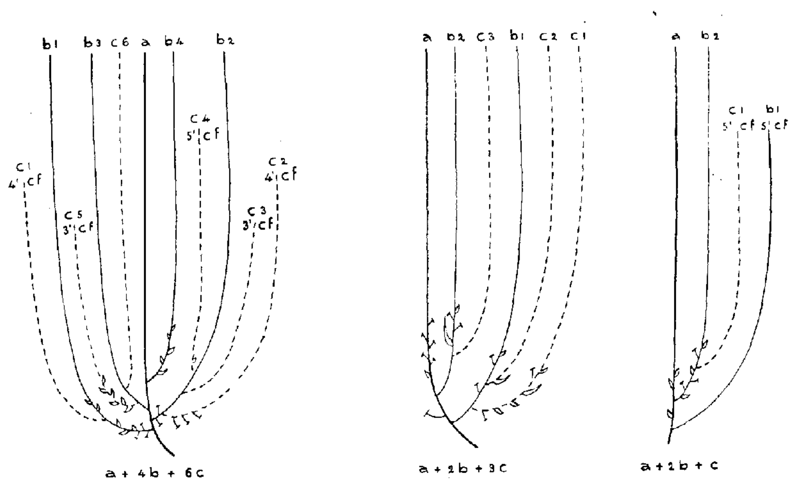
Naanal 1916 (9 months old). One clump with three plants.



Sunnabile 1916 (9 months old). One clump with two plants.

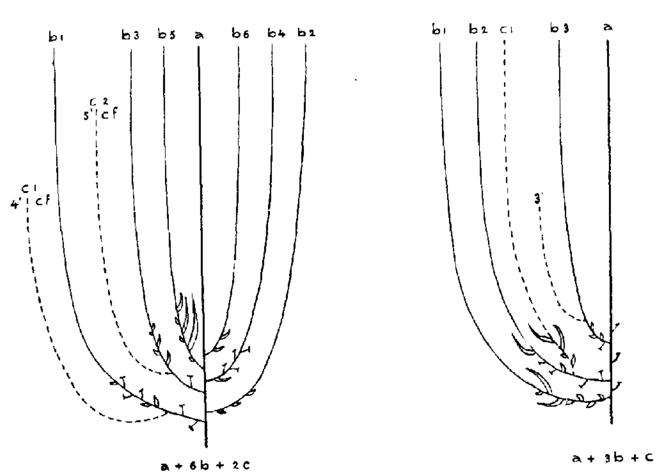
Naanal 1916 (9 months old)

One clump with three plants



Sunnabile 1916 (9 months old)

One clump with two plants



Diagrams of the branching of the five plants in the preceding plate.

FORMULÆ AND MEASUREMENTS IN THE SUNNABILE GROUP.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected		Canes at harvest					Green shoots			Bursting buds				Deaths					Grand Total	Runners
	Clumps	Plants	*a*	*b*	*c*	*d*	Total	*b*	*c*	*d*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*		
Bansa	3	6	1·0	5·2	3·0	0·8	10·0	0·2	0·8	0·8	0·5	4·7	2·5	0·7	...	2·8	17·2	3·7	0·2	44·1	0·8
Dhaulu	3	10	1·0	2·4	2·2	0·1	5·7	0·1	0·1	0·1	1·7	4·7	2·3	...	...	3·7	6·4	1·9	...	26·7	0·3
Dhor	3	8	1·0	2·0	1·9	...	4·9	2·5	0·5	0·1	0·4	4·6	7·2	...	...	4·7	4·7	1·2	...	30·8	0·0
Mojorah	2	6	1·0	4·0	1·0	.	6·0	0·2	0·3	...	0·7	7·8	0·8	...	...	5·0	14·8	0·8	...	36·4	0·3
Naanal	3	8	1·0	2·4	1·6	...	5·0	...	1·0	..	1·4	7·7	3·4	...	...	4·6	5·7	1·4	...	30·2	0·2
Sunnabile	3	8	0·9	2·7	2·5	...	6·1	...	2·2	0·7	0·9	9·1	5·7	0·4	0·1	2·4	5·2	0·9		33·7	0·7
Average	...	...	1·0	3·1	2·0	0·1	6·3	0·6	0·8	0·3	0·9	6·4	3·6	0·2	...	3·9	9·0	1·6	...	33·6	0·4

Group formulæ   Canes at harvest 1 : 3 : 2   The whole branching system 1 : 8 : 16 : 6   Runners 0

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

Variety	Average length of basal part, in inches				Average length of joints in the first two feet: Number of canes measured				Average length of joints in the first two feet: Average length, in inches				Average thickness of canes at two feet from base: Number of canes measured				Average thickness of canes at two feet from base: Average thickness, in mm.			
	a	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Bansa	2·2	1·5	2·2	2·2	5	25	12	1	1·8	2·5	3·0	2·6	6	27	9	...	169	155	178	...
Dhaulu	2·9	2·3	3·2	3·5	10	24	21	..	2·2	2·5	3·1	...	10	22	13	...	173	151	159	..
Dhor	3·2	2·5	4·6	..	4	5	7	..	1·6	2·1	2·4	...	8	17	9	...	187	200	241	...
Mojorah... ...	2·5	2·2	2·0	...	6	23	4		1·9	2·7	2·8	...	6	21	1	...	237	237	240	...
Naanal	3·2	2·4	4·5	..	5	12	7	.	2·0	2·1	3·4	...	8	18	6	.	207	203	211	...
Sunnabile ...	2·0	1·5	2·5	2·0	5	12	9	1	1·8	2·2	3·0	2·5	7	21	14	1	192	205	227	262
Average ..	2·7	2·1	3·2	2·6	...	...	...	..	1·9	2·3	2·9	2·5	...	...	.	...	189.	192	209	262

Mungo Group.

The Mungo group can at once be separated from the other indigenous canes of India by the dwarf, bushy habit of its members. This varies, it is true, in the group itself and with the locality. *Kuswar*, for instance, sometimes grows to quite a respectable height, as at Shahjahanpur and at Pusa, while it is as short as the others at Coimbatore; it is therefore somewhat difficult to draw the line, from the habit alone, between the Mungo varieties and the taller transitional forms, *Bodi*, *Sanachi* and possibly *Dhaulu of Phillaur* which have been placed in the unclassified list. But, in comparison with some others, the group is remarkably homogeneous. In the six varieties selected at haphazard for dissection, *Kharwi* shows itself to be somewhat different. in its branching and especially in the rate of cane-formation, from the rest, and *Katara* is between *Kharwi* and the others in the latter respect. But, as a whole, the group is markedly late in maturing. It must however be especially emphasized that the diagrams of canes at harvest are not altogether comparable among the varieties themselves nor with those of other groups, and for the following reasons. The shortness of the joints often causes there to be a large number of buds on the set, and a correspondingly large number of individual plants in the clump, with a consequent abbreviation of the plant formulæ. Thus, *Hemja* has fifteen plants in the three clumps, *Rheora* fourteen in three clumps, *Katara* fourteen in four clumps, *Mungo* and *Kuswar* ten in three clumps, while *Kharwi* has only four plants in two clumps. In *Hemja* two clumps have seventeen plants between them (Plate XVI), while in *Kuswar* there is one clump with only a single plant growing (Plate XXVIII). Taking these facts into consideration, the typical plant formula of canes at harvest in this group is a very extended one, being, even as it is, on a par with those of the Saretha and Pansahi groups.

In habit, the Mungo varieties assume the form of a low bush, with very short, thickish canes, and a uniform mass of drooping leaves all round. The canes are white in the Cane-breeding Station, but in North India often assume delicate rosy tints. The form of the dissected mass of canes is a rounded cup or bowl (Plate XXVIII), and the individual canes are straight or slightly curved, uniform, short-jointed and without prominent nodes, in these respects somewhat reminding one of abbreviated Sunnabile canes. The limits of the growth rings are usually very indefinite, there is a strongly marked, thin scar line, and the buds have blackened flanges. The leaves are rather narrow and the leaf sheaths long. These characters, together with the habit, make the group a very distinct one, and it is difficult to obtain connecting links between

it and the other indigenous groups, except perhaps through the *Bodi, Sanachi* and *Dhaulu of Phillaur* canes, with the Sunnabile series. Runners are not uncommon, and may be horizontal, ascending or vertical, according to need. In spite of the congested nature of the clump, curvature is not very strong, which fact we see reflected in the average length of the basal part of the cane in branches of higher orders, where it seldom reaches that in the main shoot. Variations in thickness and length of joint are also not great, which makes it difficult to separate the early and late canes at harvest. (Pls. XXVIII-XXX.)

FORMULÆ AND MEASUREMENTS IN THE MUNGO GROUP.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected: Clumps	Number dissected: Plants	Canes at harvest: a	b	c	d	e	Total	Green shoots: b	c	d	e	Bursting buds: b	c	d	e	Deaths: a	b	c	d	e	Grand Total	Runners
Hemja	3	15	0·9	1·9	1·5	0·1	...	4·3	0·5	0·9	0·3	...	2·5	4·8	2·9	.	0·1	2·7	5·7	2·3	...	27·0	0·6
Katara	4	16	0·7	2·8	2·1	0·6	0·1	6·3	...	0·9	0·2	...	2·3	10·2	6·2	1·0	0·3	2·5	7·4	2·7	0·8	40·8	0·0
Kharwi	2	4	0·7	5·0	7·7	5·0	0·2	18·6	...	1·5	0·2	...	1·7	11·7	23·0	9·7	0·3	2·7	9·0	7·7	3·7	89·8	2·0
Kuswar	3	10	0·3	2·2	3·2	3·3	0·6	9·6	...	0·6	0·7	0·4	0·6	6·8	7·3	7·3	0·7	1·4	4·8	4·6	2·9	47·7	0·7
Mungo	3	10	0·7	3·3	3·0	1·2	...	8·2	...	1·2	0·9	0·5	1·0	7·6	5·8	1·7	0·3	3·7	8·6	7·3	1·4	48·2	1·7
Rheora	3	14	0·9	2·2	1·6	0·1	...	4·8	0·1	0·3	0·1	...	2·0	6·9	4·5	...	0·1	2·0	4·2	1·9	.	26·9	0·2
Average of varieties ...			0·7	2·9	3·2	1·7	0·1	8·6	0·1	...	...	...	...	...	...		...	...	...	...	...	46·8	1·0

Group formulæ Canes at harvest 1 : 3 : 3 : 2 The whole branching system 1 : 7 : 18 : 14 : 5 Runners 1

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

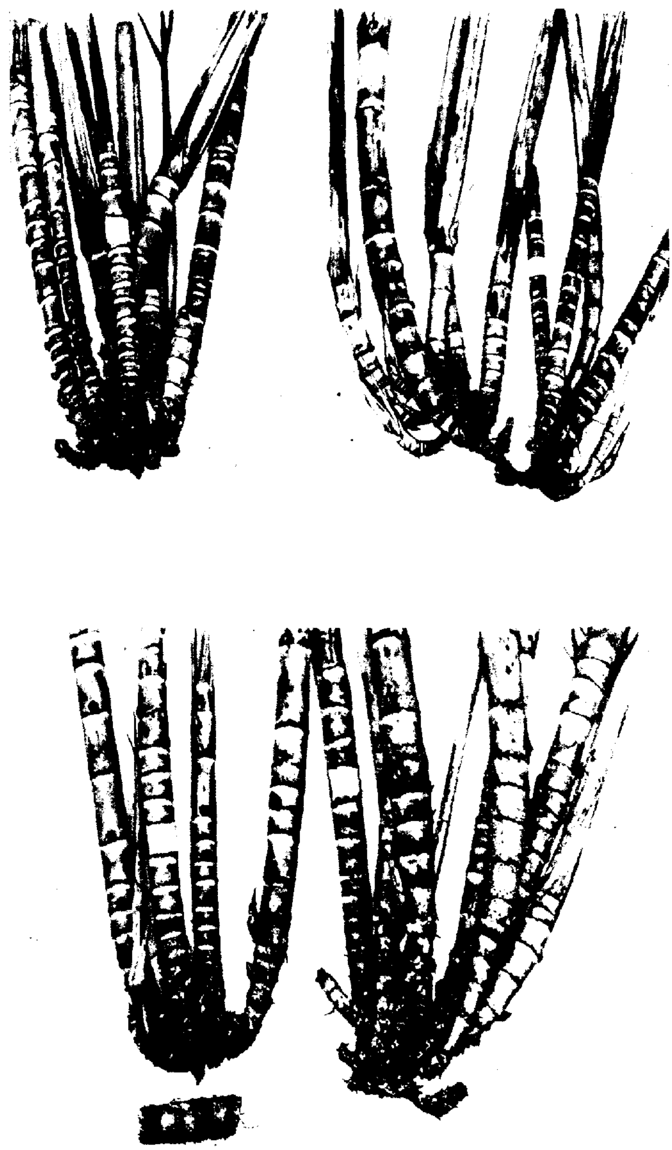
Variety	Average length of basal part, in inches: a	b	c	d	Average length of joints in the first two feet: Number of canes measured: a	b	c	d	Average length, in inches: a	b	c	d	Average thickness of canes at two feet from base: Number of canes measured: a	b	c	d	Average thickness, in mm.: a	b	c	d
Hemja	5·6	4·3	4·3	...	8	18	2	...	1·6	1·9	1·3	...	15	27	8	.	213	224	263	...
Katara	4·4	3·3	3·5	4·0	9	32	21	3	1·8	2·0	2·0	2·0	15	48	32	8	210	217	239	219
Kharwi	4·2	3·3	2·8	2·5	3	19	25	12	1·9	2·2	3·1	3·4	3	19	24	14	156	141	148	147
Kuswar	4·7	3·3	3·5	4·5	2	20	24	10	1·8	1·9	1·9	2·5	3	18	27	15	181	197	221	241
Mungo	3·9	3·5	2·6	(4·2)	6	23	18	3	1·7	2·1	2·3	2·1	7	31	25	6	187	184	198	211
Rheora	4·6	3·8	3·4	(2·0)	10	27	12	...	1·7	1·8	2·0	...	13	26	10	...	177	179	193	..
Average of varieties	4·2	3·6	3·7	3·7	...	...	...	...	1·7	2·0	2·1	2·5	...	...	...	..	187	190	210	204

MUNGO GROUP.

Hemja 1916 (9 months old). Clump before dissection (*cf.* Plate XXIX and lower diagram on Plate XXX.)

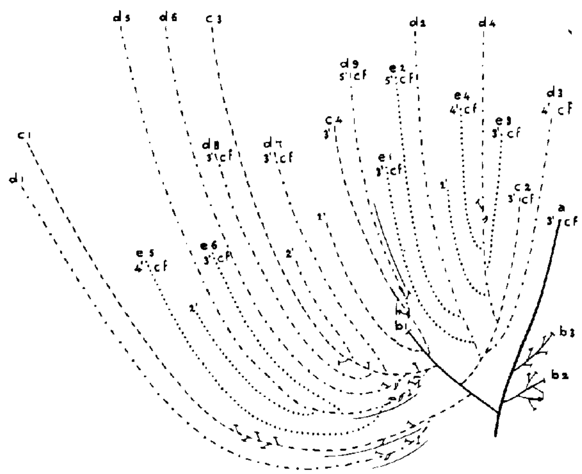
Kuswar 1916 (9 months old). Clump with only one plant (*cf.* upper diagram on Plate XXX).

MUNGO GROUP.

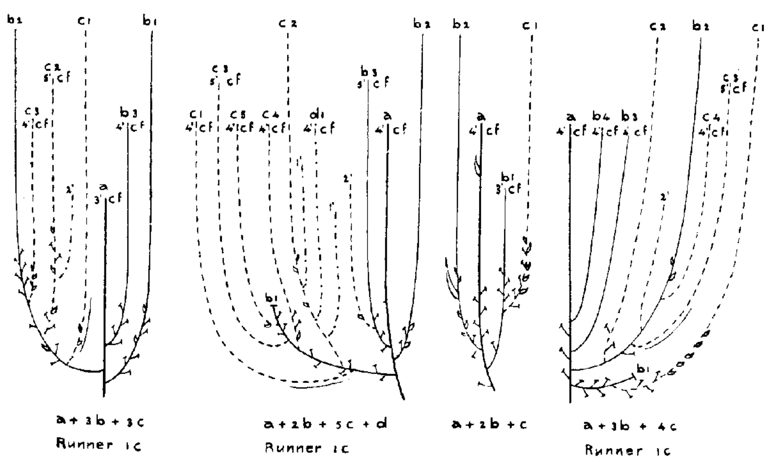


Hemja 1916 (9 months old). Clump on Plate XXVIII dissected (four plants).

Kuswar 1916 (9 months old)
One clump with only one plant



Hemja 1916 (9 months old)
One clump with four plants



Diagrams of branching of plants photographed in the two preceding plates.

Thick Cane Group.

This group, as represented in the varieties dissected, is a heterogeneous ot, taken more or less at haphazard. *Java* is a cane received from Mysore and said to have been sent there from Samalkota, but the record is lost. *Red Mauritius* is a somewhat hardy, freely tillering form, extensively grown all over the Peninsula. It was first isolated as a good variety at Samalkota and came to that place from Bombay. Judging by specimens collected in various places in North India, it has probably been in the country for a considerable time, having, as its name implies, its origin in Mauritius. The Louisiana canes were received direct from America. *Vendamukhi* and *Yerra* are apparently thick canes which have been in Bengal and Madras respectively for a long time, probably for centuries, and belong to the doubtful forms elsewhere classed as "half-thick" canes (*cf.* p. 62); there is some doubt as to their ultimate origin and affinities. As pointed out on a previous page, we have not as yet a satisfactory classification of the thick canes. With this varied character in the components of the Thick cane class dissected, it is not surprising that *Red Mauritius* and the Louisiana canes have a somewhat more extended formula than the others, but it is worth noting how little the difference really is. The average formula of canes at harvest is shorter than in any class of Indian canes.

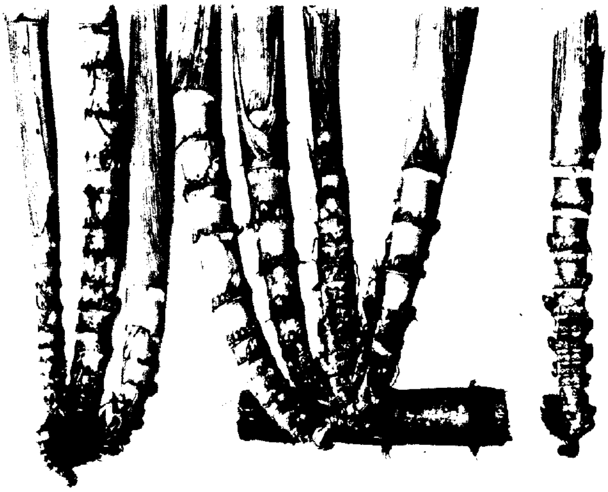
The growth of the thick canes at the Cane-breeding Station is not very satisfactory, as this class of canes requires a much better soil, with more manure and water than the native canes. Cane formation is comparatively early, most likely partly because of the few canes developed per plant. There are a great number of bursting buds as well as of deaths, both in these and in older shoots. In spite of the small number of canes per clump, there is distinct curvature in the latter canes, probably due to the thickness of the canes, but this curvature is not so great as in the Pansahi and other groups. Dissections of *Red Mauritius* canes grown at Nellikuppam have been added separately, and show the possibilities of branching in this cane in well manured, free soil. The group formula at Coimbatore is $1a+2b+1c$, and that at Nellikuppam, for *Red Mauritius* alone $1a+3b+3c+1d$. The basal part of the cane is longest in the *as*, and decreases somewhat regularly in the branches of higher orders, not being apparently interfered with by the curvature of the latter. The length of joint in the first two feet falls into line with that of the indigenous canes studied, being lowest in the *as* and increasing in successive orders of branches, and a similar increase is noticeable in the thickness of the canes at two feet from the base.

The Nellikuppam canes agree, generally, in these particulars, but the canes grown on the wet land, instead of increasing in thickness show a steady decrease. This is not at present explained, but must not be lost sight of in drawing conclusions. Separation of early and late canes in the clump should be fairly easy, but we have at present insufficient experience with this class of cane to make generalizations, and further observations are desirable.

In 1916-17, several clumps of Thick cane ratoons were dissected, and a photograph and some drawings of these are reproduced. During 1917-18 twelve clumps of *Red Mauritius* ratoon canes were dissected at Nellikuppam, half of these being in wet land and half in dry, as was the case with the twelve plant cane clumps examined there. A couple of diagrams of these ratoon dissections are added. The individual canes in these ratoons were treated in exactly the same manner as those of the plant cane clumps. Formulæ and diagrams were constructed, the length of the basal part was measured in each cane, and the average length of the joints in the lowest two feet and the thickness at two feet from the base were recorded. (Pls. XXXI–XXXIII.)

As the original *set* was in all cases still attached, we can thus obtain a very clear idea as to what takes place when a cane crop is cut and the stool allowed to grow on for another year. The analysis shows that the canes in these clumps had an average formula, in the first year, of $a + 3b + 2c$ per plant, and, in the second, of $1c + 3d + 1e$. In both of these formulæ we note that the plants in the ratooned series were less well grown than in the plant canes dissected at the same time, where the formula was $a + 3b + 3c + 1d$, and in fact the formula for each year falls into close agreement with that obtained at the Cane-breeding Station. In the diagrams, a convention has been introduced, by which each cane cut in the first year is indicated by a heavy black dot at its end. It is interesting to note that all the buds on the first year's canes have died, excepting such as grew out to form new canes in the second year. Instructive data are given as to the relative growth and ratooning power of the wet and dry land canes, but perhaps it would be better to have a larger series of figures at disposal before drawing any conclusions.

THICK CANE GROUP.

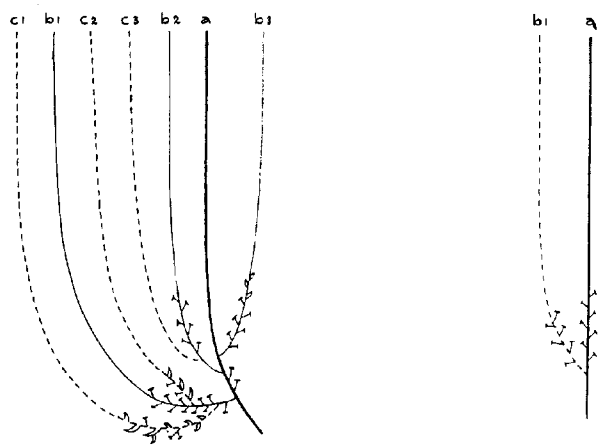


Java 1916 (5½ months old). Three plants in one clump.

Red Mauritius Ratoon 1916 (*cf.* Plate XXXIII), 20 months old.

Java 1916 (9½ months old)

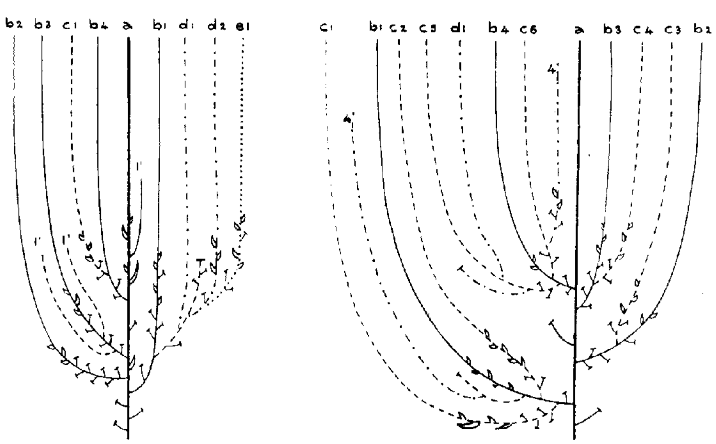
One clump with two plants



a + 3b + 3c   a + b

Red Mauritius, Nellikuppam (12 months old)

One clump with two plants

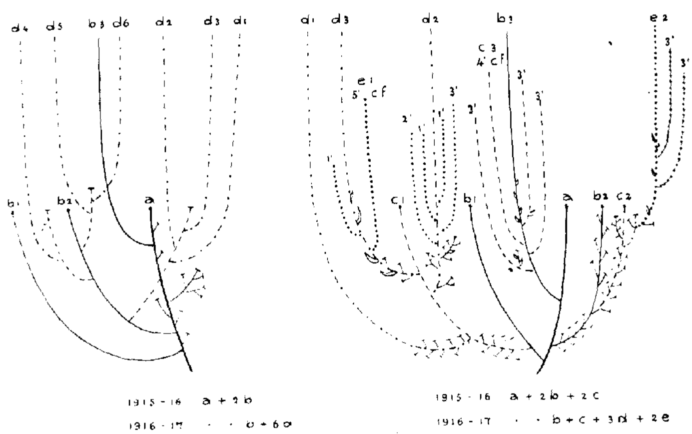


a + 4b + 1c + 2d + e   a + 4b + 6c + 1d

Diagrams of branching in thick canes at Coimbatore and Nellikuppam.

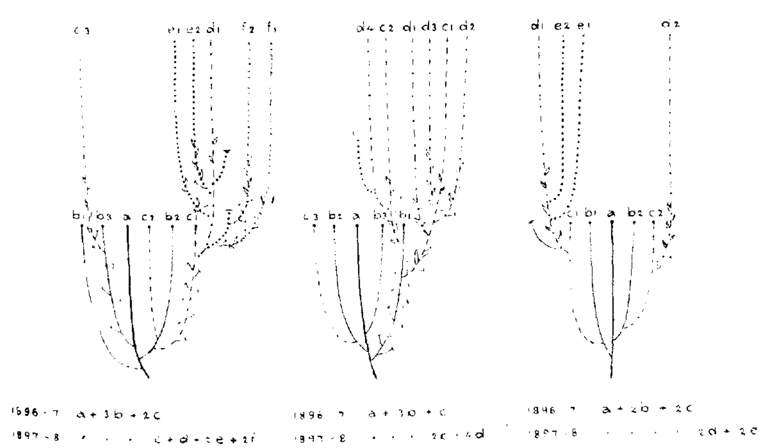
Red Mauritius Ratoons

Two ratoon plants at Coimbatore (20 months old)



(Photographed on Plate XXXI)

Three plants from one clump. Nellikuppam (25 months old)



Diagrams of the branching of *Red Mauritius* ratooned plants at Coimbatore and Nellikuppam.

FORMULÆ AND MEASUREMENTS IN THE THICK CANE GROUP.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected: Clumps	Number dissected: Plants	Canes at harvest: *a*	*b*	*c*	*d*	Total	Green shoots: *b*	*c*	*d*	*e*	Bursting buds: *b*	*c*	*d*	*e*	Deaths: *a*	*b*	*c*	*d*	*e*	Grand Total	Runners
Java	5	12	0·5	1·3	0·8	...	2·7	...	...	...	...	1·6	4·4	2·7	..	0·5	2·1	3·6	0·7		18·3	0·0
Louisiana purple	3	4	0·7	1·5	2·8	0·8	5·7	...	0·2	0·5	0·2	1·7	3·5	10·2	...	0·2	2·2	2·7	5·5	...	32·6	0·0
Louisiana striped	4	10	0·8	0·9	1·2	0·4	3·1	0·1	0·4	0·1	..	2·8	3·4	5·0	1·0	0·2	2·8	2·2	2·2	0·5	23·8	0·0
Red Mauritius	3	8	0·7	2·6	1·1	0·2	4·7	0·2	1·0	...	...	2·2	9·0	4·1	...	0·2	2·5	6·4	1·7	...	30·0	0·0
Vendamukhi	2	3	1·0	3·0	1·0	...	5·0	0·3	0·3	...	...	2·0	4·0	1·7	...	...	7·0	6·3	2·7	...	29·3	0·3
Yerra	2	4	1·0	2·5	1·2	...	4·7	...	2·0	...	...	1·7	8·0	4·5	..	...	4·5	6·2	3·5	.	35·1	0·0
Average of varieties ...		...	0·8	2·0	1·3	0·2	4·3	0·1	0·6	0·1	...	2·0	5·4	4·7	0·2	0·2	3·5	4·6	2·7	0·1	28·3	0·0

Group formulæ **Canes at harvest 1 : 2 : 1** **The whole branching system 1 : 8 : 12 : 8** **Runners 0**

Variety	Number dissected: Clumps	Number dissected: Plants	Canes at harvest: *a*	*b*	*c*	*d*	Total	Green shoots: *b*	*c*	*d*	*e*	Bursting buds: *b*	*c*	*d*	*e*	Deaths: *a*	*b*	*c*	*d*	*e*	Grand Total	Runners
Red Mauritius, Nellikuppam, Dry land ...	6	16	0·9	3·3	2·8	1·1	8·3	0·1	0·6	0·3	0·2	2·1	10 9	5·0	1·6	0·1	2·1	7·9	3·9	0·8	43·9	...
Red Mauritius, Nellikuppam, Wet land ...	6	15	1·0	2·7	2·3	0·5	6·6	...	0·3	0·7	0·1	1·9	9·2	5·9	0·7	...	1·5	7·4	4·8	0·9	40·0	...

Red Mauritius Ratoons: Formula Canes at harvest 1 : 3 : 1

—	Number dissected: Clumps	Number dissected: Plants	Canes cut 1916-17: *a*	*b*	*c*	*d*	Canes at harvest 1917-18: *c*	*d*	*e*	*f*	*g*	Total	Green shoots: *d*	*e*	*f*	Bursting buds: *d*	*e*	*f*	*g*	*h*	Deaths: *c*	*d*	*e*	*f*	*g*	Grand Total 1917-18	Runners
Dry land ...	6	10	1·0	3·1	1·9	..	1·3	2·5	0·3	0·1	0·1	7·0	0·1	1·8	0·6	4·4	9·0	7·2	2·0	0·1	...	1·3	3·2	1·3	0·9	38·9	0
Wet land ...	6	15	1·0	3·1	2·7	0·1	0·9	2·9	0·7	...	..	4·7	0·2	0·4	0·3	4·1	10·7	2·5	0·1	...	0·1	2·1	4·6	1·1	6·1	31·0	0

FORMULÆ AND MEASUREMENTS IN THE THICK CANE GROUP—*contd.*

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

Variety	Average length of basal part, in inches				Average length of joints in the first two feet: Number of canes measured				Average length of joints in the first two feet: Average length, in inches				Average thickness of canes at two feet from base: Number of canes measured				Average thickness of canes at two feet from base: Average thickness, in mm.			
	a	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Java	3·5	2·8	2·5	...	4	7	2	...	1·8	2·3	3·3	...	6	12	5	...	281	281	324	...
Louisiana purple ..	2·7	4·8	3·2	3·8	2	6	11	4	2·2	2·4	2·7	2·4	2	6	11	3	284	290	299	357
Louisiana striped ...	4·6	4·0	4·2	3·5	6	9	12	1	2·3	2·1	2·2	2·7	6	8	11	1	254	265	274	361
Red Mauritius ...	4·7	3·6	2·8	3·0	5	12	7	1	1·9	2·8	3·6	3·8	6	21	9	2	270	312	347	316
Vendamukhi ...	5·0	3·8	3·7	..	3	9	2	...	1·4	2·2	2·3	...	3	9	2	...	264	278	291	...
Yerra	5·5	3·5	3·3	..	4	8	8	...	1·5	2·2	2·8	...	4	8	3	...	226	264	257	
Average ...	4·3	3·7	3·3	3·4	...	...	...	..	1·8	2·3	2·8	3·0	..	...	...	...	263	282	298	345
Red Mauritius, Nellikuppam, Dry land	3·5	2·7	2·5	2·2	15	51	40	16	2·6	3·0	3·4	3·5	15	52	49	7	292	304	305	299
,, **Wet land**	3·5	2·8	2·5	2·3	15	38	34	7	2·6	3·2	3·3	3·3	15	41	35	8	290	274	266	270

Wild Saccharums.

The wild Saccharums, grown on the Cane-breeding Station for several years, consist of various types of *Saccharum spontaneum*, *Saccharum arundinaceum* and *Saccharum Munja*, and a single form of *Saccharum Narenga*. (Pl. XXXIV.) The two latter have at various times been more or less carefully studied and dissections made of their underground parts, but, as they do not form canes in the ordinary sense, we have been content, in the present Memoir, with reproducing the diagrams of a couple of clumps, from which their bushy, grass-like habit may be inferred. (Pl. XXXVII.) Some idea of their underground parts may be obtained from a study of the Plates in Hole's Memoir referred to above. An interesting series of crosses have been raised between the local thick *Vellai* cane and *Saccharum Narenga*, which will doubtless well repay a detailed study (*cf.* Mem. No. II, Plates IXa to XI).

(1) *Saccharum arundinaceum*, Retz., is a very distinct form. It is typically at home in the moister, eastern portions of the north of India and in parts of Burma, where it occurs wild and flowers freely. Elsewhere, although often planted and then growing well, it rarely flowers. In South India it is constantly planted around the gardens of *betel* pepper, and shows itself well adapted to heavy, water-logged soil. In spite of a diligent search during several years, only isolated cases have been met with where it was in flower, and here the inflorescence was invariably diseased. It has not therefore been possible to obtain crosses with cultivated canes on the farm.

The species is at once recognizable by its mass of tall, thick, cane-like stems, largely covered by the dead leaf sheaths, its broad curving leaves and the large, dense plumes of white or brownish flowers. The canes have fairly long joints and are distinctly noded. These are peculiar in having only one row of root eyes. The leaves are also distinguished by a mass of long brown hairs extending up the base of the lamina on either side of the mid-rib. But these hairs vary in different parts of the plant, and ultimately disappear in the upper leaves, which more resemble those of cultivated canes. These characters of leaf and joint have not been observed in any forms of *Saccharum officinarum*, which closely resembles *Saccharum spontaneum* in these and other respects. There is, of course, also the difference in the hairy vestiture of the flowers, which separates *Saccharum arundinaceum*, and puts *Saccharum spontaneum* and the cultivated canes into the same botanical section.

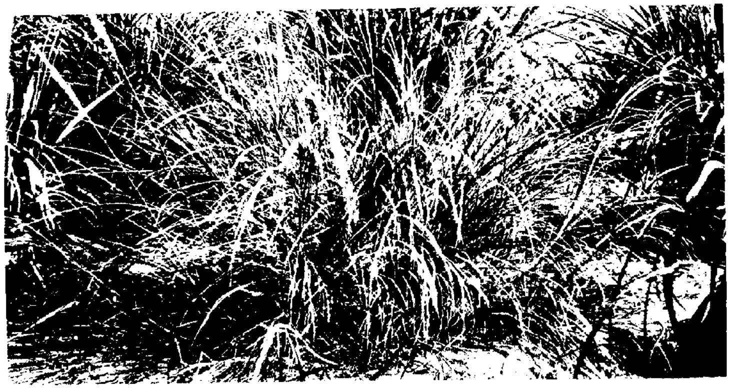
The branching of *Saccharum arundinaceum* is characterized all through by its symmetrical development. The canes are erect and parallel, often

however, bending outwards from the weight of their leafy tufts. There is comparatively little curvature, but the later shoots show this at their very base. The basal curved portion of later formed branches is characterized by its immense thickness, and by being covered by a shaggy coat made up of leaf bases, flat, scale-like buds and dense masses of brown silky hairs. This thickened part of the cane is distinctively dorsi-ventral, and the two rows of buds are thrown on to the outer portion of the curve. There are no runners. The average length of the basal part in the five plants dissected is 2·9″ in *a*, 2·1″ in *b* and 2·4″, 2·9″, 3·2″, in *c*, *d*, *e*, respectively, the small basal curvature thus having its full effect. The average length of the joint in the lowest two feet, and the thickness at two feet from the base, show continuous increases from *a* to the branches of higher orders (*cf.* Pl. I and Table appended).

(2) *Saccharum spontaneum.* Three forms of this species, among those grown at the Cane-breeding Station, have been selected for dissection, namely, the ordinary thin, grass-like form found in waste places in all parts of India, the Dacca pond form, and the Javanese variety called *Glagah*. The latter appears to be more or less intermediate between the two others, and it may be surmised therefrom that the general climate in Java is moister than that of India. There were great variations in the growth of these forms in the dissection plots, but they were all three disappointing, especially at first. This may be caused by a slow early development of the species, but is more likely due to their being unaccustomed to being grown from sets. They are capable, later on, of taking good hold of the cultivated ground, and the Dacca *spontaneum* plants, being very poor at first, formed dense masses of stalks at nine months, when grown from sets, as parents in the seedling plots. This can be readily imagined after an inspection of the diagrams on Plate XXXVI.

In habit, *Saccharum spontaneum* plants grown from seed vary a great deal (*see* Plate XXI, Mem. II), the young seedlings sometimes lying flat on the ground, and at others growing erect and branching sparsely. The general differences in appearance of the Indian varieties here discussed can be seen from an examination of Plates I and II of Mem. III. Differences in thickness are seen to be marked in these Plates. Runners are present in all the forms, those in the Dacca variety extending long distances in the mud, and, in the ordinary land form, appearing above ground at intervals somewhat widely separately from the parent stock. In the plots of seedlings raised from the different forms during the past year on the farm, there were great variations in the width of the leaves, and an analysis showed an equal difference in the sucrose content of the juice. Selections have been made in both these

1



2

3

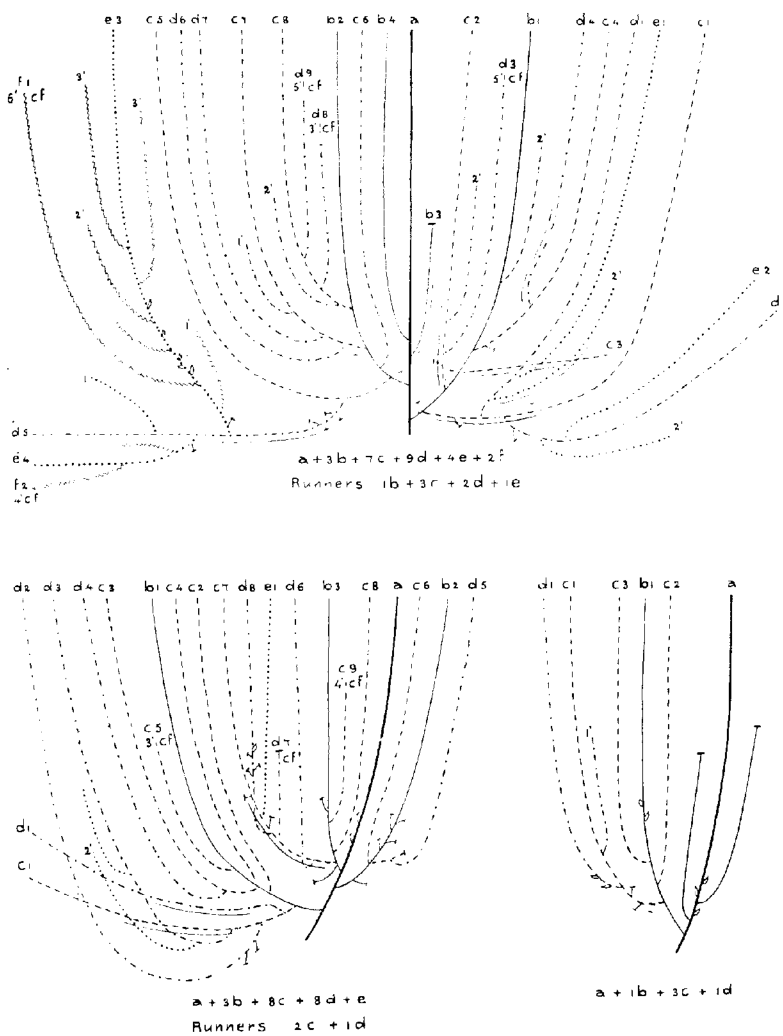
4

Wild Saccharums. Fig. 1. *Saccharum spontaneum*, common Indian form at Coimbatore. Fig 2. *Saccharum spontaneum*, broad-leafed.

Saccharum spontaneum 1917 (7½ months old)

Local Coimbatore

One clump with three plants.

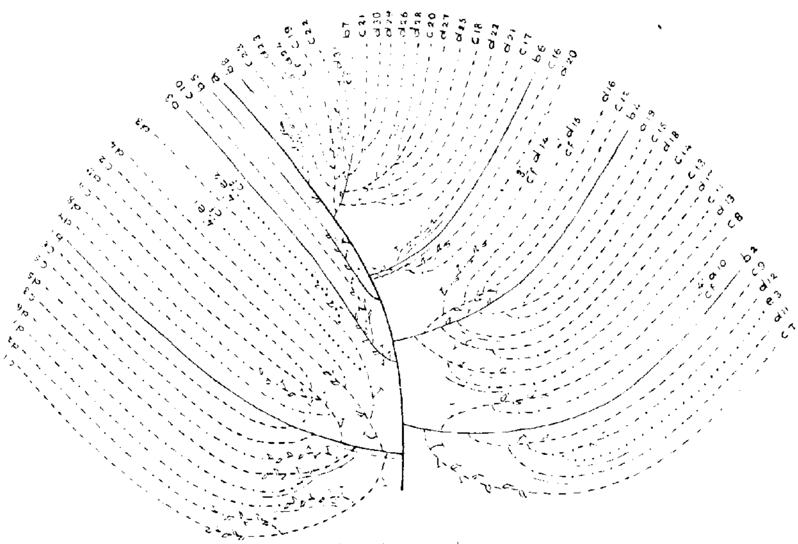


Diagrams of branching of *Saccharum spontaneum,* common Indian form, grown from a set.

Saccharum spontaneum 1917 (10½ months old)

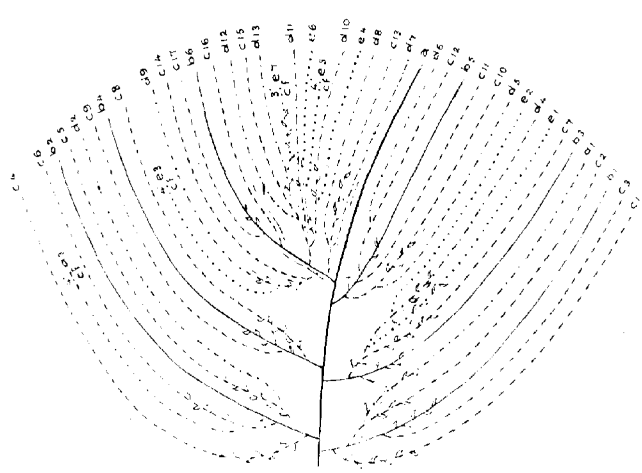
Dacca variety

One clump with two plants



a + 8b + 23c + 31d + 3e

Runners 2b + 4c + 5d + e

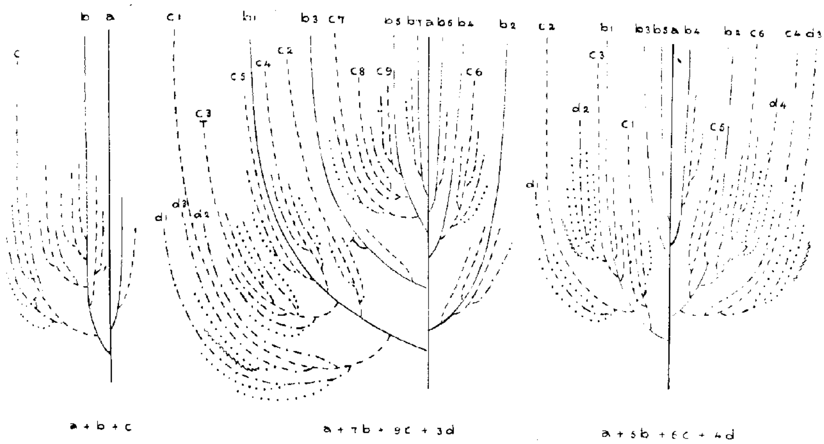


a + 6b + 17c + 13d + 7e

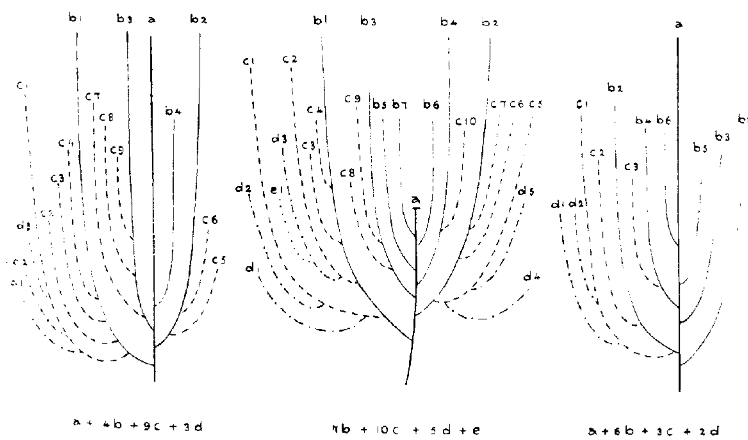
Runners 1b + 2c + 3d

Diagrams of branching of *Saccharum spontaneum,* Dacca pond form. A well grown clump grown, from a set, as parent in the seedling plots at Coimbatore.

Saccharum Munja 1917 (9 months old)
One clump with three plants



Saccharum Narenga 1917 (5 months old)
One clump with three plants



Diagrams of *Saccharum Munja* and *S. Narenga* grown from sets at Coimbatore. The branches with letters affixed had a small piece of hard cane at the base of each. The upper parts of the branches do not form cane.

directions for some years, in order to provide better material for crossing with thick canes. Already two such crosses have been distributed for trial on provincial farms. The cane formulæ obtained by dissecting plants from six to nine months agree fairly well in the three forms, being very extended. The Dacca plant, at first very backward, became extremely luxuriant at nine months and had many more branches than the others, as can be seen from the figures in the Table. In appearance, these Dacca plants are much more like cultivated canes than the other two varieties. The average length of the basal portions, the average length of joint for the first two feet, and the thickness at two feet from the base, show the regular variations met with in the cultivated canes; but, individually, the plants were often irregular in these characters. There is, in *Saccharum spontaneum*, nothing like the orderly development of the branches which characterizes *Saccharum arundinaceum*.

FORMULÆ AND MEASUREMENTS IN

1. *Formulæ of canes, shoots,*

Variety	NUMBER DISSECTED		CANES AT HARVEST							GREEN SHOOTS					
	Clumps	Plants	*a*	*b*	*c*	*d*	*e*	*f*	Total	*b*	*c*	*d*	*e*	*f*	*g*
Saccharum spontaneum — Coimbatore	3	8	1·0	2·7	5·5	4·1	1·4	0·4	15·1	0·2	0·5	1·5	1·5	1·0	...
Saccharum spontaneum — Glagah, Java	2	4	1·0	3·2	3·2	2·7	1·2	0·5	12·0	...	...	0·7	..	...	...
Saccharum spontaneum — Dacca form	4	9	1·0	5·8	10·8	7·8	2·3	0·4	28·1	...	...	...	...	...	...
Average of varieties	...	...	1·0	3·9	6·5	4·9	1·6	0·4	18·3	0·1	0·2	0·7	0·5	0·3	...
Saccharum arundinaceum	2	5	1·0	4·0	6·4	5·4	4·8	0·4	22·0	..	0·8	0·6	1·4	1·8	0·2

Species formulæ, Sacch. spontaneum, Matured canes 1 : 4 : 6 : 5 : 2 : 0·4

Sacch. arundinaceum, do. 1 : 4 : 6 : 5 : 5 : 0·4

2. *Length of basal part, and length and thick-*

Variety	Average length of basal part, in inches						AVERAGE LENGTH OF JOINTS — Number of canes measured					
	a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*
Saccharum spontaneum — Coimbatore	1·2	0·5	0·5	·6	0·6	0·6	6	16	31	21	3	1
Saccharum spontaneum — Glagah, Java	1·3	0·8	0·6	0·8	1·1	0·7	4	13	13	9	4	1
Saccharum spontaneum — Dacca form ...	1·8	1·6	1·7	2·0	2·7	..	11	57	100	66	13	...
Average	1·4	1·0	0·9	1·1	1·4	0·6	...	...	...	...	...	...
Saccharum arundinaceum	2·9	2·1	2·4	2·9	3·2	...	3	16	26	22	18	...

THE WILD SACCHARUM GROUP.

buds, deaths and runners.

Bursting buds						Deaths							Grand Total	Runners
b	*c*	*d*	*e*	*f*	*g*	*a*	*b*	*c*	*d*	*e*	*f*	*g*		
0·5	0·5	1·6	1·5	0·5	...		1·9	2·7	3·1	2·1	0·2	...	34·4	5·0
...	2·0	4·0	3·2	0·7	1·5	...	1·5	3·7	2·7	1·0	0·2	1·5	34·7	1·6
0·1	8·9	32·0	15·8	3·1	0·3	...	0·6	5·4	12·8	2·9	1·0	0·3	111·3	6·0
0·2	3·8	12·5	6·8	1·4	0·6	...	1·3	3·9	6·2	2·0	0·5	0·6	60·1	4·2
0·4	2·0	2·8	2·8	4·8	2·0	...	0·6	0·6	0·4	0·4	..	...	43·6	0

The whole branching system 1 : 5 : 15 : 24 : 11 : 3 : 1 Runners 4

do. 1 : 4 : 10 : 9 : 9 : 7 : 2 do. 0

ness of joints, in branches of different orders.

In the first two feet						Average thickness of canes at two feet from base											
Average length, in inches						Number of canes measured						Average thickness, in mm.					
a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*
3·2	3·5	3·8	4·0	3·8	5·1	8	21	35	22	6	1	68	71	71	80	73	79
2·4	3·7	4·3	5·0	5·1	4·5	4	12	13	7	2	1	62	69	84	92	85	98
2·6	3·4	3·6	3·5	3·7	...	11	57	89	57	13	...	97	99	105	108	122	...
2·7	3·5	3·9	4·2	4·2	4·8	...	...	...	...	...	...	76	80	87	93	93	88
2·1	3·3	5·2	5·8	6·5	..	5	20	31	26	23	...	153	172	209	237	237	...